TRANSACTIONS

The American Fisheries Society

1942

SEVENTY-SECOND ANNUAL VOLUME

Transactions

of the

American Fisheries Society

SEVENTY-SECOND ANNUAL VOLUME

FOR THE YEAR 1942

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Science
Zoology
Japan
2-12-46

THE AMERICAN FISHERIES SOCIETY

Organized 1870 **Incorporated 1910**

The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fishery problems.

Officers for 1942-1943*

President .... John Van Oosten, Ann Arbor, Mich.
First Vice-President .... Joe Hogan, Lonoke, Ark.
Second Vice-President .... H. H. MacKay, Toronto, Ont.
Secretary-Treasurer .... R. P. Hunter, Hartford, Conn.
Address all routine mail to the Secretary, Investment Bldg., Washington, D. C.
Librarian .... Kenneth E. Cobb, Windsor Locks, Conn

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Fish Culture .... James R. Simon, Cheyenne, Wyo.
Aquatic Biology and Physics .... R. W. Eschmeyer, Norris, Tenn.
Commercial Fishing .... W. L. Scofield, Terminal Island, Calif.
Protection and Legislation .... William C. Adams, Albany, N. Y.
Angling .... Carl D. Shoemaker, Washington, D. C.

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*For street address see membership list.

STANDING COMMITTEES, 1941-1942

Executive Committee

The Executive Committee consists of the president, vice-presidents, secretary-treasurer, vice-presidents of divisions, and James Brown, the immediate past president.

Committee of International Relations[1]

William C. Harrington, *Chairman*	Arlington, Mass.
A. G. Huntsman	Toronto, Ont., Canada
Charles E. Jackson	Washington, D. C.
A. L. Pritchard	Nanaimo, B. C., Canada
William J. Tucker	Austin, Texas
F. A. Westerman	Lansing, Mich.
E. L. Wickliff	Columbus, Ohio

Committee on State and National Relations[1]

Arthur L. Clark, *Chairman*	Jefferson City, Mo.
C. N. Feast	Denver, Colo.
John Gottschalk	Indianapolis, Ind.
Fred J. McCormac	New Orleans, La.
Frank B. Wire	Portland, Ore.

Committee on the Common and Scientific Names of Fishes[1]

Walter H. Chute, *Chairman*	Chicago, Ill.
W. A. Clemens	Nanaimo, B. C., Canada
John R. Dymond	Toronto, Ont., Canada
Samuel F. Hildebrand	Washington, D. C.
Carl L. Hubbs	Ann Arbor, Mich.
George S. Myers	Stanford University, Calif.
Leonard P. Schultz	Washington, D. C.

Committee on Publications[2]

H. J. Deason, *Chairman*	Washington, D. C.
Lauren R. Donaldson	Seattle, Wash.
Ralph Hile	Ann Arbor, Mich.
Justin W. Leonard	Lewiston, Mich.
C. McC. Mottley	Ithaca, N. Y.

[1]Elected by the membership.
[2]Each member serves for 5 years; one new member is appointed each year by the incoming President.

SPECIAL COMMITTEE[3]

Committee on Pollution Study

Kenneth A. Reid, *Chairman*	Chicago, Ill.
Carl D. Shoemaker, *Secretary*	Washington, D. C.
Seth Gordon	Harrisburg, Pa.
Francis P. Griffiths	Corvallis, Ore.
A. S. Hazzard	Ann Arbor, Mich.
S. B. Locke	Boston, Mass.
Emmeline Moore	Albany, N. Y.
James A. Rodd	Ottawa, Ont.
M. W. Smith	St. Andrews, N. B.

[3]Appointed by the President-elect, in accordance with a motion adopted by the membership.

PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1.	William Clift	1870-1872	New York, N. Y.
2.	William Clift	1872-1873	Albany, N. Y.
3.	William Clift	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877[1]	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt	1880-1881	New York, N. Y.
11.	Robert B. Roosevelt	1881-1882	New York, N. Y.
12.	George Shepard Page	1882-1883	New York, N. Y.
13.	James Benkard	1883-1884	New York, N. Y.
14.	Theodore Lyman	1884-1885	Washington, D. C.
15.	Marshall McDonald	1885-1886	Washington, D. C.
16.	W. M. Hudson	1886-1887	Chicago, Ill.
17.	William L. May	1887-1888	Washington, D. C.
18.	John Bissell	1888-1889	Detroit, Mich.
19.	Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891-1892	Washington, D. C.
22.	Herschel Whitaker	1892-1893	New York, N. Y.
23.	Henry C. Ford	1893-1894	Chicago, Ill.
24.	William L. May	1894-1895	Philadelphia, Pa.
25.	L. D. Huntington	1895-1896	New York, N. Y.
26.	Herschel Whitaker	1896-1897	New York, N. Y.
27.	William L. May	1897-1898	Detroit, Mich.
28.	George F. Peabody	1898-1899	Omaha, Nebr.
29.	John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.
35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va

[1]A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

36.	E. A. Birge	1906-1907	Grand Rapids, Mich.
37.	Hugh M. Smith	1907-1908	Erie, Pa.
38.	Tarleton H. Bean	1908-1909	Washington, D. C.
39.	Seymour Bower	1909-1910	Toledo, Ohio
40.	William E. Meehan	1910-1911	New York, N. Y.
41.	S. F. Fullerton	1911-1912	St. Louis, Mo.
42.	Charles H. Townsend	1912-1913	Denver, Colo.
43.	Henry B. Ward	1913-1914	Boston, Mass.
44.	Daniel B. Fearing	1914-1915	Washington, D. C.
45.	Jacob Reighard	1915-1916	San Francisco, Calif.
46.	George W. Field	1916-1917	New Orleans, La.
47.	Henry O'Malley	1917-1918	St. Paul, Minn.
48.	M. L. Alexander	1918-1919	New York, N. Y.
49.	Carlos Avery	1919-1920	Louisville, Ky.
50.	Nathan R. Buller	1920-1921	Ottawa, Canada
51.	William E. Barber	1921-1922	Allentown, Pa.
52.	Glen C. Leach	1922-1923	Madison, Wis.
53.	George C. Embody	1923-1924	St. Louis, Mo.
54.	Eben W. Cobb	1924-1925	Quebec, Canada
55.	Charles O. Hayford	1925-1926	Denver, Colo.
56.	John W. Titcomb	1926-1927	Mobile, Ala.
57.	Emmeline Moore	1927-1928	Hartford, Conn.
58.	C. F. Culler	1928-1929	Seattle, Wash.
59.	David L. Belding	1929-1930	Minneapolis, Minn.
60.	E. Lee LeCompte	1930-1931	Toronto, Canada
61.	James A. Rodd	1931-1932	Hot Springs, Ark.
62.	H. S. Davis	1932-1933	Baltimore, Md.
63.	Fred A. Westerman	1933-1934	Columbus, Ohio
64.	E. L. Wickliff	1934-1935	Montreal, Canada
65.	Frank T. Bell	1935-1936	Tulsa, Okla.
66.	A. G. Huntsman	1936-1937	Grand Rapids, Mich.
67.	I. T. Quinn	1937-1938	Mexico City, Mexico
68.	Fred J. Foster	1938-1939	Asheville, N. C.
69.	T. H. Langlois	1939-1940	San Francisco, Calif.
70.	James Brown	1940-1941	Toronto, Canada
71.	John Van Oosten	1941-1942	St. Louis, Mo.
72.	John Van Oosten	1942-1943	(No meeting.)[2]

[2]The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.

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PART I
REPORTS

REPORTS OF OFFICERS

THE CANCELLATION OF THE SEVENTY-SECOND ANNUAL MEETING OF THE AMERICAN FISHERIES SOCIETY

JOHN VAN OOSTEN, *President*

It was with deep regret that we found it necessary to cancel the seventy-second annual meeting of the American Fisheries Society scheduled to be held at New Orleans, Louisiana, September 16-17, 1942. In order that this unprecedented postponement of an annual meeting of our Society may be understood clearly, especially in the future, it is believed desirable to review briefly for the record the background of events that formed the basis of action.

On April 8, 1942 the Executive Committees of the International Association of Game Fish and Conservation Commissioners and the American Fisheries Society decided at their joint session in Toronto, Ontario, that because of war conditions the meetings of the two organizations should be restricted to a total of four days. A very timely and important program was planned for the Society's convention. A symposium was scheduled on "Fishery Management in the War," which would have emphasized the special fishery problems arising because of the war.

On June 25, 1942 a circular letter was sent to each member announcing, among other items, the time and place of the seventy-second annual meeting of the Society, and requesting on an enclosed postal card notification of intention to attend the conference. A similar canvass of the membership was made by the International Association of Game, Fish and Conservation Commissioners.

In view of the trend of the replies which indicated that only a few members would attend the meeting, the President wrote each member of the Executive Committee of the Society under date of July 16, 1942 as to the action that should be taken and the procedure that should be followed if cancellation were deemed advisable. Advice was also sought on the publication of the *Transactions,* if the conference were deferred.

The returns of the canvass showed that out of 213 members who replied, 15 would attend, 41 hoped to attend, and 157 would not attend. In view of these results and the existing conditions due to war the Executive Committee decided to cancel the scheduled convention at New Orleans and to resume the annual meetings when the situation warranted. Further reasons for cancellation were: (1) The deferment of the convention of the International Association of Game, Fish and

Conservation Commissioners; (2) the general request of the Director of the Office of Defense Transportation of the Executive Office of the President that all conferences not absolutely essential for purposes of war be postponed; (3) the rationing of rubber tires and gasoline; and (4) the threatened rationing of public transportation.

The Executive Committee also decided to continue the publication of the *Transactions* as usual in order to make available for distribution the papers that had been planned for submission at the New Orleans meeting, particularly those that are of special interest under the present exigencies of war.

The officers of the Society and chairmen of committees have been requested to submit their reports so that information on developments in the various fields of the fisheries may be brought up-to-date.

I feel confident that in the light of the above review the members of the Society will concur in the actions taken by its Executive Committee and officers.

At this time I would like to recommend that at the next meeting of the Society the constitution be amended to cover any future emergencies that would require the cancellation of a regularly scheduled convention. It is believed that Articles IV, VI, and VIII should be amended. Recommendations will be made at the proper time.

Finally I wish to express to the Department of Conservation of the State of Louisiana, on behalf of the Society, its regret of the turn of events which made impossible the holding of the convention scheduled at New Orleans and to assure our disappointed host that the Society is nevertheless deeply grateful for the kind invitation extended. The cancellation was to us a real sacrifice made necessary by the war. It is hoped that conditions will soon make possible a resumption of our annual meetings. In the meantime may I urge the members to keep an active interest in the Society. Pay your dues! Continue your efforts to obtain new members! Keep your Society alive! Keep it growing!

REPORT OF THE SECRETARY-TREASURER
For the Year 1941-1942

R. P. Hunter

I regret that the report of the Secretary-Treasurer for the fiscal year ending June 30, 1942 does not look too encouraging from the standpoint of membership statistics. At the close of the fiscal year we dropped 17 active members, 10 libraries, 4 clubs and dealers, and 5 states. During the year, 7 members tendered their resignation, a few

for the duration of the war only. Through death we lost 7 members. Our total losses were 110. The states which have been dropped from the rolls are California, Mississippi, New York, Pennsylvania, and South Dakota. For some unaccountable reason, we are not holding our new active members for any length of time. Of the active members dropped for the nonpayment of dues, 27, or 35 per cent, paid dues for only 1 year, while 11, or 14 per cent, carried on for 2 years.

The number of new members added during the year is just one-half of the number in all classes dropped. The new-member tally includes 48 active members, 1 club, and 6 old members reinstated, making a total of 55.

Let me urge upon you the importance of interesting your associates in the work of the Society. Naturally, we are going to lose many of our members for the duration of the war and if the Society is to carry on on a sound financial basis and pay its way, we must enlarge our membership. Let each one put his shoulder to the wheel to see if the 1942-1943 year can't be made one of the best in spite of the present world-wide crisis.

Now for the financial report. While our bank balance as of June 30, shows a somewhat larger figure than last year, yet if the bill for the printing of Volume 71 of the *Transactions* had been presented, it would have been necessary to borrow from the permanent fund to meet the indebtedness or withhold full payment until the Treasury was in a better financial condition. If the billing for dues for the coming year had been mailed earlier in the month of June, the bank balance would have reflected an even larger amount. The Society has no indebtedness other than the printing bill which had not been presented at the close of the fiscal year since the volume was not off the press.

The bank balance in the general fund as of June 30, 1942, was $1,037.54, in the permanent fund, $1,495.47.

At the annual meeting in Toronto (1940), the sum of $250.00 was appropriated from the general fund for the photostating of missing volumes of the *Transactions* needed to complete two sets for the permanent library and for the binding of all these volumes. Since this work was not completed during the fiscal year 1940-1941, and since it was felt that the amount appropriated would not cover the complete cost, an additional $250.00 was appropriated from the permanent fund at the St. Louis meeting (1941). This work has been completed at a cost of $437.00, a saving of $187.00. These bills were paid in full from the general fund. It will be necessary, therefore, to transfer from the permanent fund to the general fund the sum of $187.00.

Dr. H. J. Deason is to be commended on his untiring efforts in collecting and binding this permanent library and in effecting a saving to the Society.

TREASURER'S REPORT
July 1, 1941—June 30, 1942

GENERAL FUND

RECEIPTS		
Balance on hand July 1, 1941		$ 435.36
Annual dues		
Individuals:		
For the year 1938-1939	$ 12.00	
1939-1940	24.00	
1940-1941	105.00	
1941-1942	809.22	
1942-1943	45.00	995.22
Libraries:		
For the year 1940-1941	20.00	
1941-1942	66.00	86.00
Clubs and Dealers:		
For the year 1940-1941	5.00	
1941-1942	85.00	90.00
State Membership:		
For the year 1940-1941	20.00	
1941-1942	580.00	600.00
Exchange on checks		.40
Sale of *Transactions*		347.89
Sale of Index		5.00
Sale of reprints 1940 *Transactions*		568.97
Total receipts		$3,128.84
DISBURSEMENTS		
Transactions:		
1940, Vol. 70		
Reprints		$ 662.23
1941, Vol. 71		
Reporting	$ 195.80	
Proofreading and editorial expense	125.00	320.80
Clerical and secretarial expense:		
R. P. Hunter	100.00	
Ethel M. Quee	300.00	400.00
Postage		84.55
Exchange on checks		2.21
Stationery and printing		146.50
Rental safe deposit box		6.00
General expense		2.40
Premium on bond		18.75
Photostating *Transactions*		360.00
Binding *Transactions*		77.00
Office Supplies		6.66
Express		4.20
Total disbursements		$2,091.30

Total receipts General Fund	$3,128.84	
Total disbursements General Fund	2,091.30	$1,037.54
Balance on hand, July 1, 1942	$1,037.54	
Balance in Petty Cash Fund	5.00	
Balance on hand, July 1, 1942	$1,042.54	

PERMANENT FUND

RECEIPTS

Balance on hand, July 1, 1941	$1,141.55
Interest on Savings Account	21.94
Interest and principal Montgage Certificates	301.98
Dividends on Commonwealth Southern pfd.	30.00
Total	$1,495.47

DISBURSEMENTS

None	
Balance on hand, July 1, 1942	$1,495.47
Par value of certificates other than Government Bonds	5,000.00
Par value of 10 shares Commonwealth Southern pfd.	1,000.00
Par value of Government Bonds	1,650.00
Total	[1]$9,145.47

[1]The cash value of the 10 shares of Commonwealth and Southern Preferred, par value $100.00, as of July 1, 1942, was $251.25.

LIST OF AMERICAN FISHERIES SOCIETY SECURITIES

A list of securities owned by the American Fisheries Society as of July 1, 1940, was published in the *Transactions*, Vol. 70, pp. 24-25. No changes in the holdings of the Society had occurred by June 30, 1942, and therefore the complete list is not published in this report of the Treasurer for the year 1941-1942.

In Memoriam

A. F. Byers, Montreal, Canada

Robert W. Goelet, New York, N. Y.

Harry Johnson, Verdi, Nev.

Glen C. Leach, Washington, D. C.

J. M. Merritt, Gretna, Neb.

C. D. Ryan, Concrete, Wash.

George Shiras, 3d, Marquette, Mich.

PART II
PAPERS

Harris and Ewing, Washington, D. C.

GLEN C. LEACH—1872-1942

M. C. James
U. S. Department of the Interior, Fish and Wildlife Service, Chicago, Illinois

The American Fisheries Society is the forum in which all factors and developments influencing fishery conservation can be reviewed, considered, and discussed. Some factors and influences, and the discussions which result from them, usually center around research, techniques, and abstract conceptions. In the summing up, it will probably be conceded that individual men, their personalities and abilities, and the things that they have done have most profoundly influenced the trends of fish culture and fishery conservation. When an individual has devoted himself to fish-cultural activities for 40 years—more than half the span of the modern era of fish culture—and when he has occupied a dominant position in this field for a quarter of a century, his career, his accomplishments, and his personality surely merit more than a perfunctory comment in the annals of this Society.

In assigning to Glen C. Leach a dominant status in the field of fish culture, I believe I am doing no injustice to the many other individuals who have built up records of outstanding accomplishment. Nevertheless the Federal Division of Fish Culture, regardless of the departmental banner which might wave over it, has had and has the most extensive, widespread scope of activities of any agency of its kind in the world. It is inevitable that the man whose foot was on the accelerator of this organization (Glen had no use for the throttle) would wield a powerful influence in all phases of practical fish propagation. Glen C. Leach undoubtedly has designed and supervised the building of more fish hatcheries than any other one man. He has supervised the work of more fish-culturists than any other single individual. Administratively he had to concern himself with such out-of-the-ordinary and little-known enterprises as hatching the spiny lobster and stone crab in Florida as well as the more routine functions of producing billions of young marine food fishes, hundreds of millions of Pacific salmon and myriads of game fish. The number of young fish which started toward their ultimate destiny, uncertain as it might be, under his direction during his tenure of office staggers the imagination. But I really do not believe that it is necessary to build up a case to show that Glen C. Leach was a figure of consequence in his chosen field.

Convention compels the erection of a structure of biographical facts, although I would much prefer to dwell on the more personal aspects of an association of 15 years duration. Born at Ackley, Iowa, September 18, 1872, he secured his common-school and high-school education at Oswego, Kansas, and followed this with 2 years at Washburn College at Topeka, Kansas. Later he was enrolled at a business col-

lege and an engineering school at St. Louis. I have never learned the exact nature of his activities between his school years and his first entrance into the Federal Government service in 1901, but an occasional typical Leach anecdote indicated that the period was far from humdrum. His initial role in public service in the St. Louis postoffice was of short duration, terminating with his appointment as fish-car laborer for the old U. S. Fish Commission in December 1902. His career for the succeeding 12 years, a progressive advancement through the various field positions of the Division of Fish Culture, was not unlike that of many other employees except that his advancement was relatively rapid. During part of the period he was rated as machinist at the Put-in-Bay, Ohio, station (now closed), and his interest in things mechanical was ever evident. Plenty of field duty, including a tour of service at the Yes Bay, Alaska, salmon hatchery, came his way. Although such is not revealed by the bare facts of his service record, it appears that he was rated unofficially as a trouble-shooter, and, as is often the case with a man who does not shrink from the "headache' assignments, he went ahead rapidly. His initial appointment as station superintendent at Manchester, Iowa, in 1914 lasted only 2 years when he was given Washington duty as field superintendent. In 1918, while Dr. Hugh M. Smith was Commissioner of Fisheries, Leach succeeded Henry O'Malley in full charge of the Division of Fish Culture.

During several war and post-war years the going was a bit rough, but this was soon followed by an upswing which reached its peak in the years following the enactment of the White Act in 1930. This legislation authorized the establishment of numerous new hatcheries throughout the country over a period of 5 years, and although some of the projects are yet to be started, it gave Glen Leach 10 years of the kind of activity he loved. The box-score tells the story. When he took over the Federal hatchery system, it numbered 75 units. When failure of his powerful physique forced him to relinquish the helm, there were 133 units. Production had increased from about 5 billion to over 8 billion fish and eggs during his stewardship. New and improved methods, and new and improved equipment and facilities, some of which he designed, were in general use when he left the picture.

Leach served during a period when it was widely accepted that more and bigger hatcheries were the basic need in fishery husbandry. Regardless of whether we now accept that thesis in its entirety, Glen met that demand in a thoroughly workmanlike and efficient way. The fish-cultural establishments which he built in a dozen different states are concrete testimony to his all around ability and to his special interest in construction.

In serving as advisor, often unofficially, to a number of State fish and game departments, his influence extended beyond the Federal organization.

The "Manual of Fish Culture," that bulky testament of an earlier

generation of hatcherymen, appeared in its final revision in 1900. Midway in Leach's career the "Manual" practically disappeared from circulation, having acquired the inevitable fungus of obsolescence in the two decades. Glen C. Leach met the obligation of providing a substitute as a glance at the following partial list of Government publications bearing his name will reveal:

"Artificial propagation of sturgeon," Report U. S. Commissioner of Fisheries, 1919 (1920), 5 pp. (B. F. Doc. 880.)

"Artificial propagation of whitefish, grayling, and lake trout," Report, U. S. Commissioner of Fisheries, 1923, 32 pp., 42 figs. (B. F. Doc. 949.)

"Artificial propagation of brook trout and rainbow trout, with notes on three other species," Report, U. S. Commissioner of Fisheries, 1923 (1924), 74 pp., 22 figs. (B. F. Doc. 955.)

"Artificial propagation of shad," Report, U. S. Commissioner of Fisheries, 1924 (1925), 28 pp., 8 figs. (B. F. Doc. 981.)

"Artificial propagation of pike perch, yellow perch, and pikes," Report, U. S. Commissioner of Fisheries, 1927, 27 pp. (B. F. Doc. 1018.)

"Culture of rainbow trout and brook trout in ponds," U. S. Bureau of Fisheries, Economic Circular No. 41, 1919, 19 pp.

"Cooperative fish culture," U. S. Bureau of Fisheries, Economic Circular No. 59, 1926, 8 pp.

From their very nature these issues were compilations, but they contained much that is source material since their author had actually carried on the techniques he described, and had devised and improved the equipment he prescribed.

The index of the *"Transactions"* of this Society shows an impressive list of contributions from his pen, and he served as its president in 1922-1923. He was a long time member of the Izaak Walton League, and a member of the Masonic Order. Sportsmen's organizations in all parts of the country knew him and benefited from his shrewd advice. He was just as anxious to be helpful in restoring some child's pet goldfish to buxom health as he was in straightening out more complex and perplexing problems.

My personal affection for him inevitably leads me into reference to his personality and character even though I am writing for a group which knew him well. Many of you will remember his wholehearted participation in arguments and debates on the numerous moot questions of our profession, and will recall his shrewd, sometimes biting, comments. Not so many may have noted the twinkle in his eye while the debate raged, or that slow, broad grin which mantled his face at the conclusion whether he was winner or loser. No one can think of him without thinking of his sense of humor, but one had to be close to him to see that sense of humor in its finest flowering. Of course it could have been coincidence that during his absence on official trips, we at the office would receive crank letters of the most outrageous na-

ture signed with some ridiculous name and seething with indignation at our official follies. The fact that these letters were postmarked in some small town where Glen was condemned to spend a dull evening subjected the theory of coincidence to terrific strain. Nevertheless the customer is always right, and we never dared to follow our convictions and reply in kind. While he got a lot of fun out of the various minor predicaments in which unwary humans inevitably entangle themselves, he was unremitting in his efforts to help in the untangling process. This sense of humor sparkled unclouded even to the moment when he lapsed into final coma.

One other trait was dominant in his personality. This was loyalty. He was loyal to those who were in authority over him, and if their policies and beliefs were in conflict with his own, his execution of unwelcome tasks was no less conscientious and vigorous. He was loyal to his own views and beliefs and fought for them tenaciously. He believed in conservation, and his championship of its broad principles was uncompromising although he accepted compromise on questions of ways and means. He devoted himself to his job, and his unwillingness to slow down official activities in the face of impaired health undoubtedly contributed a considerable measure to his final illness. Above all he was loyal to those in whom he placed his confidence and trust—his friends. His solicitude for those who worked under him took precedence over his personal interests and welfare. He was a staunch defender of the Division of Fish Culture and those who worked in it. Those who worked under him doubly appreciated the calm, placid temperament which rarely erupted into anything resembling strong feeling. When the boiling point occasionally was reached, it subsided quickly and there was no aftermath of resentment or ill feelings.

Glen Leach's contributions to fish culture were real and significant, but in my personal scheme of things his shrewd leadership, kind advice and counsel, and tolerant, sound judgment were of greater consequence. The guild of fish-culturists has lost one of its ablest practitioners, but of infinitely greater concern to me and to hundreds of those in the Society is the loss of one who was a friend in the fullest meaning of the word.

THE ANAESTHESIA OF FISH BY HIGH CARBON-DIOXIDE CONCENTRATIONS

Frederic F. Fish

U. S. Department of the Interior, Fish and Wildlife Service
Seattle, Washington

Abstract

A practical and economical method for anaesthetizing adult salmon and steelhead trout in the fish trucks used in the Grand Coulee fish salvage program is described. The method consists in generating a predetermined carbon-dioxide concentration in the 1000-gallon tanks of the trucks through the successive addition of predissolved sodium bicarbonate and dilute sulphuric acid in proper quantities. Carbon-dioxide anaesthesia effectively solved the acute problem of species segregation in the fish salvage program and, with minor modifications, could be used with equal success in certain hatchery operations necessitating the handling of large fish.

The problem involved in handling very large fish often becomes serious in certain types of hatchery operations. The streamline form and slippery mucous coating of a fish offer a precarious handhold at best, yet a minimum of pressure must be exerted against the struggling animal to avoid risk of inflicting injury. The use of anaesthesia has been proposed to facilitate those operations that do involve the handling of large fish but the cost of the usual anaesthetics enforces a limiting factor over the quantities which can be used. This situation greatly nullifies the value of anaesthesia for if a hatcheryman must pick up a fish and immerse its head in a limited quantity of an anesthetizing solution, he might as well proceed with his work on that fish without benefit of anaesthesia.

A particularly acute need for a practical and economical method for immobilizing fish arose in the operations of the Grand Coulee Fish Salvage Program. In this work, adult migratory fish are trapped in the fishways of the Rock Island Dam below Wenatchee, Washington, and transported in large tank trucks a distance of 40 miles to retaining ponds in which they are held until the onset of sexual maturity. Concurrent runs of fish arriving at the Rock Island Dam do not necessarily attain sexual maturity at the same time. The so-called "fall" steelhead trout and chinook salmon are trapped simultaneously during the summer. The chinook salmon will mature during the autumn months but the steelhead trout will not be ready for spawning until the following May or June. If these two species are placed in the same retaining pond, many of the "green" steelhead trout will become involved in the artificial propagation of the chinook salmon. This

practice invariably has led to considerable damage being inflicted upon, and with subsequent loss of, a large number of the steelhead trout.

Manifestly, it would be difficult to remove a dozen 6-pound steelhead trout without injury from a truck containing perhaps twenty 30-pound chinook salmon and an incidental hundred miscellaneous scrap-fish—all being confined in a 1,000-gallon tank of water. Therefore, some means of immobilizing and sorting each mixed load of fish became imperative.

The quantity of water involved rendered impractical usage of any of the anaesthetics commonly employed in experimentation on fish. Even if the tank were half-drained, a minimum of 40 pounds of ether would be required for each load. Cresol approached practicability from the standpoint of cost but it proved entirely too variable in its effect and subsequent toxicity to be trusted. The stunning of the fish by electrical shock was considered but competent authorities, experienced in the results obtained from electric fish screens, definitely warned against the injurious effects which could be expected from the use of electricity on large fish.

The lead to a successful and economically practical method came from experiments conducted by Mr. Mitchell G. Hanavan, aquatic biologist of the Fish and Wildlife Service, who was studying the effects resulting from the sharp and sudden decrease in carbon dioxide concentration experienced by fish dumped from the Grand Coulee fish trucks, in which the carbon dioxide had accumulated during the 40-mile trip, into holding ponds at equilibrium with the atmosphere. Mr. Hanavan found one load of adult fish completely anaesthetized following the experimental production of an abnormally high carbon dioxide concentration by the direct application of the gas through the air inlet of the water recirculating system.

Further exploration of this lead demonstrated that carbon dioxide concentrations in excess of 200 p.p.m. were effective anaesthetics for both fingerling and adult salmon. Introducing the gas via the air inlet of the truck proved unsatisfactory because anaesthetizing concentrations could not be developed in less than one-half hour during which time the fish thrashed about wildly in the tank. Increasing the rate at which the gas was administered resulted only in a greater esçape. Even when applied at a very slow rate through an efficient Venturi, less than one-half of the gas dissolved in the water. The minimum cost of administering an anaesthetizing concentration by the direct application of carbon dioxide gas was about $1.00 per load.

Because of the difficulties encountered in dissolving the carbon dioxide gas directly in the water, an alternative of generating the required amount in the tank by the successive addition of predissolved sodium bicarbonate and dilute sulphuric acid was attempted. Not only was the escape of the gas from the water virtually negligible, but the concentration attained could be predicted accurately from the ratios

between the molecular weights of the compounds involved. By using the technical grade of reagents—making due allowances for the impurities present when calculating the quantities required—the cost of effectively anaesthetizing the fish was reduced to approximately $0.40 per load. This method was developed specifically for application to the Grand Coulee fish-trucks although it could be applied with equal success to meet comparable problems encountered in other hatchery operations.

Carbon dioxide concentrations ranging between 150 p.p.m. and 650 p.p.m., as determined by titration with N/44 sodium hydroxide, were tried on an experimental basis. It was found that the higher the concentration used, the quicker was the effect and the shorter was the period of exposure which the fish would tolerate. Water temperatures between 45° F. and 60° F. exerted relatively little effect although, in general, the higher the temperature, the more rapid was the effect obtained. Adult steelhead trout and chinook salmon could remain in a concentration of 400 p.p.m. for as long as 20 minutes after insensibility was attained with no apparent permanent ill effect. After about 5 minutes in a concentration of 400 p.p.m., however, there was definite evidence of a physiological derangement as the fish appeared temporarily distressed upon return to water bearing a normal complement of carbon dioxide. To avoid this presumably undesirable consequence and yet prolong the period of anaesthesia, the high carbon dioxide concentration in the tank could be eliminated at will by neutralization with predissolved sodium carbonate. The fish would then remain in an anaesthetized state for an additional 5 to 10 minutes and upon revival exhibit no evidence of distress.

The optimum carbon dioxide concentration for anaesthetizing all species of salmon and steelhead trout was found to be 200 p.p.m. As this concentration is developed in the tank by the soda-acid technique, the fish swim restlessly about at the surface but exhibit no evidence of marked distress nor even a significant increase in their rate of respiration. They gradually lose consciousness, turn over, and sink to the bottom within a period of 90 seconds after the full strength is attained. They lie motionless on the bottom, their respiration rate being maintained without change although the depth of each respiratory movement gradually lessens and finally ceases. After all evidence of respiration has disappeared, the fish will not revive when placed in fresh water. The depth of respiration, therefore, becomes a valuable index of the approaching lethal endpoint.

The Grand Coulee fish trucks, for which the described anaesthetizing technique was developed, are essentially 15-ton trucks each bearing a water tank of 1,000-gallon capacity. On the top of each tank is a large rectangular hatch, the cover of which can be rolled back for loading. The tank is equipped with a recirculating water system discharging 125 gallons per minute and aerating the water by passage through a

Venturi. The recirculating pump also may be used to add water to the tank from outside sources for tempering purposes.

In the routine anaesthesia of mixed loads, as practiced in the Grand Coulee fish salvage operations, the tank is drained to approximately 600 gallons upon arrival of the truck at the point of sorting. The reduction in the volume of water present not only lessens the quantities of reagents required for the anaesthesia but likewise enables the sorter to work directly in the tank. After drainage is completed, the hatch is opened and the proper quantity of sodium bicarbonate, predissolved in a pail, is added directly to the tank. A marked rise in the bicarbonate (methyl orange) alkalinity and the pH accompanies the addition of the bicarbonate. About 5 minutes is then allowed for the recirculating system to disperse the bicarbonate homogeneously. During this period, the necessary quantity of sulphuric acid is diluted approximately 1:500 in a barrel placed alongside the truck. The air inlet to the Venturi is then closed to avoid a subsequent sweeping out of the carbon dioxide from the water and to increase visibility for the sorter. Immediately thereafter, the dilute acid is drawn into the tank from the barrel through a 2-inch flexible hose connected to the outside pump line. The acid is added only as rapidly as it is neutralized by the bicarbonate—a matter of 2 to 3 minutes. If the acid enters at a faster rate, localized areas of hyperacidity develop in the tank which usually promote a general stampede by the fish. Addition of the acid sharply reduces the bicarbonate alkalinity and the should not exceed 5 minutes, the high carbon-dioxide concentration is When the fish are anaesthetized, the sorter enters the tank and removes the desired species. After a minimum period of exposure, which should not exceed 5 minutes, the high carbon-dioxide concentration is neutralized by the proper quantity of sodium carbonate predissolved in the barrel and added in the same manner as the acid. The carbonate quickly restores the original carbon dioxide concentration although a higher pH remains because of the bicarbonates present as an end product of the reaction between the carbon dioxide and sodium carbonate. After sorting is completed, the hatch is covered and the remaining fish hauled to a second pond and dumped. If this haul is to be an extended one, the water in the tank is replaced with fresh water as a precautionary measure.

This method of administering anaesthesia is not as complex as the description might imply. Reasonable accuracy is required in determining all values although a considerable variation in the carbon dioxide concentration is permissable and no ill effects result.

With minor modifications, carbon-dioxide anaesthesia can be applied to other hatchery operations. It has been used, for example, to facilitate spawning operations with steelhead trout merely by maintaining a satisfactory high carbon-dioxide concentration in a barrel of water into which an attendant dip-nets the fish and from which the spawn-taker removes the insensible fish as needed. In this appli-

cation, no carbonate is required for the fish are removed well within the 5-minute tolerance period after insensibility has been reached.

Carbon dioxide anaesthesia has been tested under actual field conditions during the past 2 years and has proven eminently satisfactory when properly applied. It must be recognized that certain hazards are connected with the storage and handling of sulphuric acid. Use of this method is not advised except under the direct supervision of an individual sufficiently well grounded in chemistry to handle concentrated acid capably, to calculate the quantities of reagents required, and to make frequent carbon-dioxide determinations as a check upon the accuracy of the results obtained. Under such supervision, carbon-dioxide anaesthesia may fill a very definite need in certain types of hatchery operations involving the handling of large fish.

VITAMIN B_1 DEFICIENCY IN HATCHERY REARED RAINBOW TROUT

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ABSTRACT

A nutritional disease of trout, caused by a diet deficient in Vitamin B_1 (thiamin), is described. The symptoms are attributable, either primarily or secondarily, to malfunctioning of the nervous system and are: Loss of equilibrium accompanied by whirling, melanotic appearance, inability to feed in the latter stages of the disease, progressive weakness, and a final paralysis. It was produced in the laboratory by feeding a diet known to be lacking in thiamin. The disease was cured by injections of thiamine hydrochloride.

In 1939, during a routine investigation of a disease occurring in a State-operated trout hatchery a peculiar ailment was observed in rainbow trout fingerlings. Since that time this same malady has occurred in other hatcheries of the state at different times of the year and in various sizes of fish but up to late 1942, had been observed only in rainbow trout.

The disease was identified as a nutritional disorder caused by a deficiency of Vitamin B_1 in the diet and experimental evidence has confirmed this diagnosis.

Schneberger (1941) gave a brief resume of the cause and treatment of this disease in Wisconsin and the following paper gives in detail the data upon which this summary was based.

Wolf (1942) described a Vitamin B_1 deficiency in trout in the New York hatcheries caused by feeding raw fish in the diets of trout and gives an adequate review of the literature on this subject. The raw fish tissue as shown by experimental evidence, has the power of destroying Vitamin B_1 in other elements of the dietary mixtures thus rendering deficient a diet that might otherwise contain an adequate amount of this vitamin. Wolf found in one experiment that brown trout were more susceptible to the disease than brook trout or rainbow trout but that one strain of rainbow trout was more susceptible than another.

SYMPTOMS AND PATHOLOGY OF VITAMIN B_1 DEFICIENCY

In the epidemic studied in most detail the affected fish were a group of approximately 10 thousand rainbow trout varying in length from 45 to 90 millimeters. They had been fed, during the early part of the summer, on a diet of canned carp supplemented with liver and melts in an approximate ratio of 90 per cent canned carp, 4 per cent

fresh pork melts and 6 per cent fresh pork liver. Five days before the first-noted symptoms of the disease the fish were placed on a straight canned-carp diet with no fresh meat or other supplement. A later analysis of the canned carp for Vitamin B_1 showed it to be devoid of this substance.[1]

In other observed epidemics the appearance of the disease was always preceded by a diet composed mainly of canned carp with some fresh meat supplement, but usually not enough to supply the requisite amount of Vitamin B_1.

The disorder followed a well-defined course with very definite symptoms attributable either primarily or secondarily to malfunctioning of the nervous system. The symptoms are given below in general order of their appearance.

The fish were not able to maintain their normal upright position but showed a tendency to swim at an angle to the vertical plane. As the affected fish became sicker the angle increased until the fish would, when swimming, lie practically on their sides. A sudden blow on the side of the tank would stimulate them to great activity and for a second or two they would swim normally and would then relapse to the "side swimming" position. Concommittant with the side swimming was a giddiness and whirling which became more pronounced as the loss of equilibrium increased. This action appeared intermittently with the fish acting normally between spasms.

Coincidentally with the increase in whirling the fish became weaker. After a spasm of gyration the trout would fall to the bottom and remain motionless for some time. The weakness could be attributed partially to starvation.

During the early stages of the disease the affected fish did not eat normally and in the later stages did not eat at all. The cessation of feeding appeared to constitute an inability to take food rather than a lack of desire to eat. Many times fish would, even in the latter stages of the disease, pick up a mouthful of food and then reject it, much as if they were hungry but were unable to swallow because of paralyzed throat muscles.

One of the most universal symptoms was a pronounced darkening of the fish due to the expansion of the melanophores. The affected fish could be readily identified by their dark color alone without reference to other symptoms.

In a small, but significant percentage of the fish, the air bladder became so distended by gas that the fish would float at the surface of the water totally unable to control their buoyancy.

As the fish grew weaker they would lie on the bottom for longer and longer periods of time until finally they appeared to become completely paralyzed and would lie dormant moving only with the currents of the water. This constant moving back and forth on the bottom

[1]This analysis was made by Mr. La Vell Henderson of the University of Wisconsin Biochemistry Department.

of the tank first wore away the scales at the point of contact, then the skin and finally the flesh, producing as an end result a large open wound. No primary infection was found in this wound and it showed no evidences of healing. It had much the appearance as if a circular piece of flesh and skin had been removed with a sharp scalpel.

A detailed pathological examination of the dead and dying fish revealed no organisms capable of causing the symptoms and pathology above described. A few fish were mildly affected by fin rot, and *Octomitus* was found in two or three fish but neither of these diseases was present in any significant number of the fish.

No gross pathology was observed. The various organs of the body were apparently normal with the exception of the air bladder which in a few instances was markedly distended with air.

From the symptoms, pathology, and diet of the affected fish it was concluded that they were suffering from some neural disease brought on by a dietary deficiency. Since Vitamin B_1 deficiency causes a neuritis in certain vertebrates it was decided by analogy that this vitamin might be the deficient factor. Accordingly a tentative diagnosis of a neural disease due to Vitamin B_1 deficiency was made.

Experimental Treatments

To check the diagnosis of a Vitamin B_1 deficiency a number of fish in the poorest condition were placed in aquaria and injected with synthetic Vitamin B_1, thiamin hydrochloride. Table 1 presents the results.

Table 1.—Results of the intramuscular injection of sick rainbow trout with various amounts of synthetic Vitamin B_1 or thiamin hydrochloride

Milligrams injected	Number of fish injected	Condition of fish 22 hours after treatment			
		Recovered	Partial recovery	Unaffected	Dead
0.05	11	9	1	1	0
0.10	11	5	3	0	3
0.15	11	7	2	0	2
0 20	8	6	0	1	1
Control	14	0	4	9	1

As may be seen from the table there was a very definite improvement in the fish injected with the thiamin hydrochloride. The losses in the treated groups may be in part attributed to the fact that the fish treated were very sick and the handling and injection may have been enough to cause death.

Concluding from these preliminary data that the diagnosis of Vitamin B_1 deficiency was correct, treatment was made on a larger scale. Eighty of the sickest fish were selected and separated into two equal lots, one of which was injected intramuscularly with 0.2 to 0.4 milligrams of thiamin hydrochloride, the dose varying with size (0.2 milligrams for fish ranging from 45 to 65 millimeters and 0.4 milligrams

for those ranging from 66 to 90 millimeters in length). The others were left untreated as a control. At the end of two days the results were as follows:

Fish	Dead	Recovered	Unaffected
Treated	2	37	1
Control	1	0	39

As a very definite benefit was evident in the above treatment another experiment involving a larger number of fish was set up to compare intramuscular and intraperitoneal injections. Two hundred and fifty of the sickest rainbow trout were selected and divided equally among five tanks. In two of the tanks the fish were injected with thiamin hydrochloride intramuscularly, in one tank they were injected intraperitoneally, and two tanks were left as controls. The results at the end of four days are shown in Table 2.

Table 2.—Results of injection of sick rainbow trout intramuscularly and intraperitoneally with thiamin hydrochloride

Locale of injection	Milligrams injected	Number of fish dead	Partial to complete recovery	Unaffected
Intramuscular	1.0	2	40	8
Intramuscular	2.0	9	38	3
Intraperitoneal	2.0	0	48	2
Control	0.0	1	0	49
Control	0.0	1	0	49

It was concluded from the favorable results of this and previous experiments and from general observations that the injections should be made intraperitoneally as this mode of injection seemed to do less damage to the fish.

Effect of Vitamin B_1 Injections upon Metabolism of Affected Trout

To determine the effect of injections of thiamin hydrochloride upon the metabolism of trout suffering from the Vitamin B_1 deficiency 12 of the sickest fish were selected, care being taken to have them as near to the same weight as possible. These 12 trout were separated into two groups, one group was left untreated and each fish of the other group was injected intraperitoneally with 2 milligrams of thiamin hydrochloride. Each group was placed in a respirometer and allowed to remain in total darkness during the remainder of the experiment. At the end of 24 hours the oxygen uptake of each group of fish was measured for a period of 4 hours and the values averaged and compared. The results showed that the treated fish 24 hours after treatment averaged an oxygen uptake of 3.5 times that of the untreated fish.

The recovery of the fish following the injection of synthetic Vita-

min B_1 into the fish seemed to amply confirm the diagnosis of an avitaminosis due to B_1 deficiency. Accordingly the remainder of the sick fish were injected with 1 milligram of thiamin hydrochloride intraperitoneally and were quite fully recovered when the observations were concluded.

Artificial Production of Thiamin Deficiency

A group of yearling rainbow trout were held in indoor tanks using a filtered water supply to exclude all natual food. These fish were fed only on canned carp, which, according to analysis, is practically devoid of thiamin. The feeding continued for 5 months before any symptoms of thiamin deficiency appeared. At the end of approximately 5½ months most of the fish were suffering from the disease and exhibiting the same symptoms as described above.

The fish upon examination failed to show any parasites or disease and recovered upon injection of thiamin hydrochloride.

Prevention of the Disease

To prevent further occurrences of this malady a supplement of dried brewer's yeast is added to the diet of all trout when the diet is low in thiamin. The supplement of yeast has been quite successful in preventing the occurrence of the disease and has been useful in curing epidemics when they were detected in time to add it to the diet while the fish could still eat.

Literature Cited

Schneberger, Edward

1941. Fishery research in Wisconsin, U. S. Fish and Wildlife Service, Prog. Fish-Cult., No. 56, pp. 14-17.

Wolf, Louis E.

1942. Fish-diet disease of trout. A vitamin deficiency produced by diets containing raw fish. New York State Conservation Department, Albany, N. Y., Fish. Res. Bull. No. 2, pp. 1-16.

A POPULATION STUDY OF A LIMITED AREA IN A MICHIGAN TROUT STREAM, SEPTEMBER, 1940[1]

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ABSTRACT

A population study was conducted on 580.5 feet of Hunt Creek, a tributary of the Thunder Bay River, in Montmorency County, Michigan. Hunt Creek was open to public fishing over its entire length during the 1940 trout season. A combination of stream diversion, blocking and seining, and finally poisoning with rotenone, enabled the investigators to obtain a capture of all fish in 0.131 acres of stream. The total fish population consisted of 605 brook trout weighing 12.36 pounds, and 188 muddlers weighing 1.27 pounds. From these data it was computed that Section C of Hunt Creek was supporting 4,619 brook trout (weight, 94.40 pounds) and 1,435 muddlers (weight, 9.68 pounds) per acre. Of the 605 brook trout captured, 2.3 per cent (14) were legal-sized (7 inches, total length or longer); 22.0 per cent (133) were between 4 and 6.9 inches; and 75.7 per cent (458) were between 2 and 4 inches long. Two and one-half times as many legal-sized brook trout were captured in the deeper portion of the area as in the shallower region. Analysis of the data indicates that seining as a method of capture, even in blocked-off portions of trout streams, has an efficiency of no more than about 80 per cent, as far as number is concerned.

Data on the growth of brook trout, derived from a random series of scale samples, indicate that the brook trout do not reach the legal size of 7 inches until their third or fourth summer. Calculations based on the data available from the scale readings, and the length-frequency distribution of the total population, indicated the distribution of the age-groups among the actual population was as follows: O—46.7 per cent; I—30.8 per cent; II—19.8 per cent; III—2.7 per cent.

The calculated survival from 1,000 young-of-the-year brook trout was found to be as follows: 0—1,000; I—659; II—424; III—58.

The average coefficient of condition (K) of the brook trout population was determined to be 1.469 (144 specimens of a size range of 4.0 to 9.5 inches, total length). This value is somewhat higher than those reported by other authors, possibly because of the time of year when the investigation was conducted.

INTRODUCTION

The comparative scarcity of published studies of trout-stream populations leads the authors to hope that the data presented here may be of interest to fishery biologists concerned with trout-stream problems. The entire fish population of a short stretch of stream was available for examination. There follows a description of the physical conditions in the region and of one method of study, together with an analysis of the fish population made from various standpoints, including

[1]Contribution from the Michigan Institute for Fisheries Research.

that of age and growth, apparent mortality between age groups, and difficulty of capture.

In the Hunt Creek experimental area, located in southern Montmorency County, Michigan, various parts of Hunt Creek have been given special designations, on an ecological basis, to aid in evaluating the results of an intensive creel census. Other research requirements made it desirable to construct a series of by-pass channels, which could be screened and controlled, near the middle of a 3,970-foot-long stretch of stream designated "Section C."[2] After the new channels were excavated, the entire flow of the stream was diverted through them, so that concrete bulkheads could be placed across the original channel. The diversion of the water presented an excellent opportunity to study the entire fish population of the section of stream thus cut off, in a manner similar to that described by Embody (1929). Seining and treatment with rotenone were employed in addition to water diversion to insure a complete count of all fish present in the delimited area.

The delimited area consisted of two contiguous, arbitrarily designated sections which, to conserve space, will be known hereafter as II-A and III-A. Together, these sections comprised 580.5 feet of stream with a total surface area of 0.131 acre. Individually, III-A, the upper of the two sections, has a length of 298 feet, an average width of 9.2 feet, and a surface area of 0.063 acre; II-A has a length of 282.5 feet, an average width of 10.5 feet, and a surface area of 0.068 acre. Stream flow, at the time of the study, was approximately 6,500 gallons per minute at a surface velocity varying, throughout the area, from 1 to 2.5 feet per second, as determined with a Bentzel velocity tube. The water supply is almost wholly of spring origin. In the sections concerned, dissolved oxygen is usually present at the concentration of 10.5 p.p.m.; dissolved carbon dioxide has never been found in excess of 2 p.p.m.; and is usually absent; methyl-orange alkalinity is about 175 p.p.m.; and the pH varies from 7.8 to 8.0 as determined with a Hellige pocket comparator. Throughout both sections the stream bottom is gravelly, composed of smoothly rounded glacial-drift material ranging in size from that of a pea to that of a man's two fists. The average is about the size of a hen's egg. Very little sand is exposed in the bottom, except for occasional bars formed behind natural obstructions.

Bottom-fauna investigations indicate that in both II-A and III-A the average square foot of bottom yields about 0.750 cubic centimeters of bottom organisms during September. Larvae and pupae of caddisflies, especially those of *Mystrophora americana,* surpass both mayflies and aquatic Diptera in number and volume. Common mayfly nymphs are those of *Baetis vagans* and *B. brunneicolor, Paraleptophlebia praepedita* and *P. mollis,* and *Ephemerella invaria.* Among stoneflies, only nymphs of *Isogenus frontalis* are often significant volumetrically, al-

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[2]Surface area, 1.07 acres, as determined from a plane-table map drawn to a scale of 1 inch = 20 feet.

though nymphs of *Capnia manitoba, Allocapnia torontoensis, Leuctra* sp. and *Nemoura* spp. are numerically abundant.

The stream banks, which are seldom over 1 or 2 feet high, support a mixed open stand of alder (*Alnus incana*), tamarack (*Larix laricina*), white cedar (*Thuja occidentalis*), and aspen (*Populus tremuloides*). Aquatic vegetation is of negligible amount in the sections considered here. There are a few small beds of speedwell (*Veronica connata*); and algae (*Vaucheria* sp.) form mats over the infrequent sandy areas.

Procedure

On September 25, 1940, at 7:30 a.m., blocking seines of ⅜-inch bar measure were doubled and placed across the stream simultaneously at points X and Y (Figure 1), and at the same time the flow was diverted into the bypass channel by means of a tight sandbag dam at point Z. The lead lines of the blocking seines were held tightly to the stream bottom and the intersections with the bank by a continuous row of large stones placed on each line. The entire fish population in II-A and III-A was thereby trapped. In about 45 minutes most of the normal water content had drained out of the area cut off, and the fish present were concentrated in 20 to 30 small and more or less isolated pools.

At this time seining was begun; a 4-by-4-foot common-sense minnow seine was used. All water areas were seined throughly, and most of the fish were taken in this way. Of the few fish taken by hand or with scap nets, the majority were muddlers (*Cottus b. bairdii*). The only trout in the area were eastern brook trout (*Salvelinus f. fontinalis*). All fish captured were transferred to a tub of fresh water, and later were counted and weighed by species. Trout of legal size (7 inches or longer, total length) were weighed and measured individually and scale samples taken; measurements and scale samples were taken from a representative series of the smaller trout. All fish taken by seining were released alive below the lower blocking net after being weighed and measured. The entire day of September 25 was devoted to capturing and recording the fish taken by seining.

Although nearly 6 hours of intensive seining effort had been expended on less than 600 feet of stream, a small but noticeable number of trout and muddlers remained in the blocked-off area of stream. It was decided to leave the blocking seines in place over night, and to treat the pools with poison on the following morning. Accordingly, on September 26, at 7:15 A.M., with the air temperature at 38° F. and that of the water at 44° F., 200 grams of powdered derris root (5 per cent rotenone content) were mixed with 5 quarts of water, and a small portion of the mixture was sprinkled over the surface of each pool in III-A, the upper of the two sections. After about 10 minutes, trout and muddlers remaining in the area began to die, and were collected by hand or with scap nets.

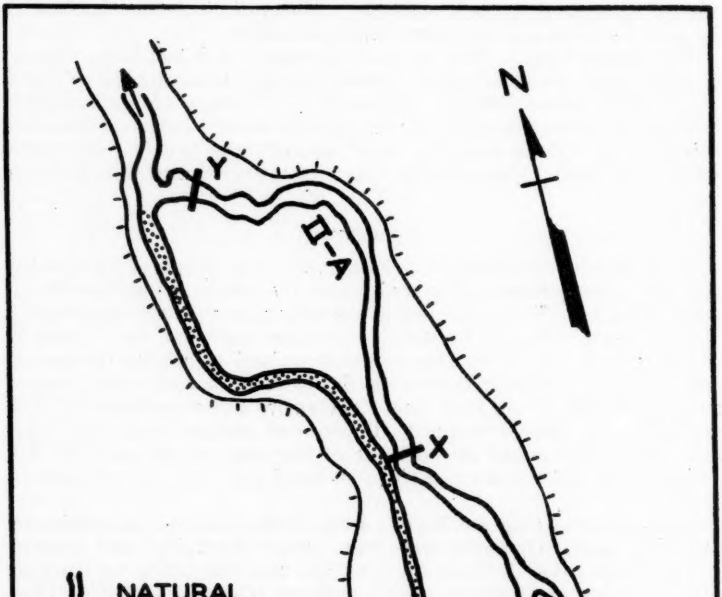

FIGURE 1.—Map of stream area of Section C of Hunt Creek, Montmorency County, Michigan, on which the population study was made. (See text for significance of X, Y, and Z.)

Because of spring seepage from the banks and bottom of the stream, the isolated pools gradually spilled over, and the poisoned water from III-A was slowly forced into II-A, where its concentration proved sufficient to kill fish that had escaped capture by seining there. To prevent possible mortality of trout below the area under observation, a sand-and-gravel dike was thrown acoss the steam below the blocking net at point Y (Figure 1), and the poisoned water pumped out of the lower end of II-A by means of an engine-driven diaphragm pump having a capacity of 100 gallons per minute. Operation of the pump for a 4-hour period removed most of the poisoned water. A small notch was then cut in the dike and the remaining water allowed to drain slowly from the isolated area. A careful inspection of Hunt Creek on the following day indicated that no mortality occurred below the isolated area.

Fish Population of the Drained Areas

Only two species of fish were present in II-A and III-A: Eastern brook trout (*Salvelinus f. fontinalis*), and muddlers (*Cottus b. bairdii*). From III-A, with a length of 298 feet, an average width of 9.2 feet, and a surface area of 0.063 acre, a total of 345 trout and 90 muddlers was recovered. From II-A, the lower section, with a length of 282.5 feet, an average width of 10.5 feet, and a surface area of 0.068 acre, 260 trout and 98 muddlers were taken. Combining results, it may be seen that 605 trout and 188 muddlers were removed from 580.5 feet of stream having a surface area of 0.131 acre. A further analysis

Table 1.—Data on fish population of Diversions II-A and III-A of Section C of Hunt Creek, Montmorency County, Michigan, on September 25, 26, 1940

Item	Number captured	Total weight (pounds)	Calculated number per acre	Calculated pounds per acre
Diversion II-A (area 0.068 acre)				
Brook trout:				
7 inches or longer	10	1.64	147	24.08
4-6.9 inches	79	3.52	1,162	51.76
less than 4 inches	171	1.43	2,514	21.06
Muddlers	98	0.64	1,441	9.43
Total	358	7.23	5,264	106.33
Diversion III-A (area—0.063 acre)				
Brook trout:				
7 inches or longer	4	0.75	63	11.97
4-6.9 inches	58	2.55	921	40.44
less than 4 inches	283	2.47	4,492	39.22
Muddlers	90	0.63	1,429	9.94
Total	435	6.40	6,905	101.57
Total area censused (0.131 acre)				
Brook trout:[1]				
7 inches or longer	14	2.39	107	18.26
4-6.9 inches	137	6.07	1,046	46.33
less than 4 inches	454	3.90	3,466	29.81
Muddlers	188	1.27	1,435	9.68
Total	793	13.63	6,054	104.08

[1]The average total length of the 14 legal brook trout was 7.81 inches; the average total length of the sublegal brook trout was 5.12 inches (137 specimens measured); the average total length of the fingerling brook trout was 2.83 inches (51 specimens measured).

is shown in Table 1. On the basis of measurements of the area and the total number of fish recovered, it was found that this section of the experimental stream was supporting fish at the rate of 4,619 brook trout and 1,435 muddlers per acre, or, in terms of weight, held 94.4 pounds per acre of trout and 9.68 pounds per acre of muddlers. It should be mentioned that an unknown but probably small number of legal-sized trout may have been removed from the restricted study area during the angling season which closed on September 4, 1940.

Of the 605 brook trout captured, 40 were marked fingerlings of hatchery origin. Thirty-nine of these fish were released in Section C in August, 1940; one was from a planting of hatchery-reared fingerlings made in the section in October, 1939. The hatchery-reared trout made up 6.7 per cent of the total brook trout population; all were less than legal length (7 inches) at the time of the study. By weight, hatchery trout made up 2.7 per cent of the calculated total. As all the trout planted in Hunt Creek since 1938 have been marked, all unmarked tout were presumably of natural origin.

Length Distribution of the Trout Population

Data from all specimens obtained from II-A and III-A were combined to draw up a length-frequency table (Table 2 and Figure 2). The table and the figure show that a great majority of the brook trout

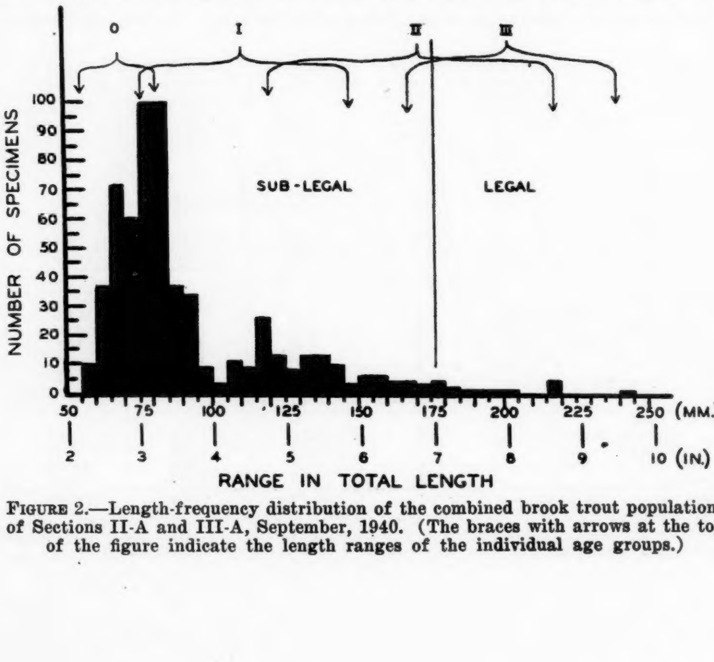

Figure 2.—Length-frequency distribution of the combined brook trout populations of Sections II-A and III-A, September, 1940. (The braces with arrows at the top of the figure indicate the length ranges of the individual age groups.)

present were fingerlings (less than 4 inches, total length). Of the 605 trout captured, 2.3 per cent (14) were 7 inches or more in length; 22.0 per cent (133) were between 4 and 6⅞ inches and were classed as "sublegal"; and 75.7 per cent (458) were fingerlings. By weight, legal-sized trout made up 19.4 per cent, sublegal fish 48 per cent, and fingerlings 32.6 per cent of the total weight of the trout captured.

Comparison of the Populations of the Two Areas

The populations of II-A and III-A have been calculated separately to determine what differences existed in the components of the total population. The lower section, II-A, was slightly the larger, had more and larger pools, and better underwater cover. In II-A the pools had an average depth of 1.2 feet while those of III-A averaged 1.0 feet. In II-A was found the larger number of legal-length brook trout (10 as

Table 2.—Length-frequency distribution of brook trout found in Diversions II-A and III-A, Section C, Hunt Creek, September 25, 26, 1940

[Includes 40 marked hatchery trout]

Range in total length, (millimeters)	Number of specimens in group[1]	Range in total length, (millimeters)	Number of specimens in group
55- 59	10	155-159	6
60- 64	37	160-164	4
65- 69	71	165-169	4
70- 74	60	170-174	3
75- 79	100	175-179	4
80- 84	100	180-184	2
85- 89	37	185-189	1
90- 94	34	190-194	1
95- 99	9	195-199	1
100-104	3	200-204	1
105-109	11	205-209	..
110-114	9	210-214	..
115-119	26	215-219	4
120-124	13	220-224	..
125-129	8	225-229	..
130-134	13	230-234	..
135-139	13	235-239	..
140-144	10	240-244	1
145-149	3		
150-154	6	Total	605

[1]The length-frequency distribution of brook trout less than 100 millimeters total length was determined from a sample of 174 fish from Section C measured on September 24, 1940. The percentages of fish in each size range of the latter sample was applied to the total number of fish classed as "fingerlings" in the population count. This procedure was followed because of lack of time to measure all trout captured.

compared with 4), and also the larger number of sublegal fish (79 as compared with 58). The number of fingerlings, however, was considerably less (171 as compared with 283) than in the smaller and slightly shallower upper section. Corresponding calculations on numbers and pounds per acre exhibited similar differences. The total poundage of fish removed from III-A was at the rate of 101.57 pounds per acre as compared with 106.33 pounds per acre for II-A. (Table 1.)

An Analysis of Difficulty of Capture

Of some interest was the degree of difficulty with which the brook trout and muddlers of various sizes were captured. Seining activities were initiated as soon as the water level had dropped to a point where there was little flow between pools, and continued about 3.5 hours in the morning of the following day. By that time it was thought that more than half of the fish present had been removed. In both diversions, exactly 50 per cent of the legal-sized brook trout, roughly one-half of the sublegal trout, and approximately 63 per cent of the fingerlings were taken in the morning seining. Capture of the muddlers varied considerably; in III-A about 41 per cent were taken in the morning seining, while in II-A only 3.1 per cent had been taken at that time (Tables 3 and 4).

In III-A, the percentage of brook trout removed by seining (both afternoon and morning) was 91.9 while poison accounted for 8.1 per cent (27 fingerlings and one sublegal trout). The percentage of all fish removed, trout and muddlers combined, was 81.4 per cent by seining and 18.6 per cent by poison. The rotenone was especially helpful in recovering small muddlers, which often escape a net by burrowing in the gravel and rubble of the bottom.

In II-A, the percentage of trout taken was 86.2 by seining, and 13.8

Table 3.—Analysis of difficulty of capture of fish population of Diversion III-A, September 25 and 26, 1940

Date and method and time of capture	Item	Number	Total weight (grams)	Percentage of	
				Total number	Total weight
September 25 (Morning seining)	Brook trout:				
	Over 7 inches	2	143	50.0	41.8
	4-6.9 inches	33	716	56.8	61.9
	Less than 4 inches	184	706	65.0	62.9
	Muddlers	37	157	41.2	55.2
September 25 (Afternoon seining)	Brook trout:				
	Over 7 inches	2	199	50.0	58.2
	4-6.9 inches	24	429	41.5	37.1
	Less than 4 inches	72	327	25.4	29.1
	Muddlers	....	....	0.0	0.0
September 26 (Poisoning)	Brook trout:				
	Over 7 inches	....	....	0.0	0.0
	4-6.9 inches	1	11	1.7	1.0
	Less than 4 inches	27	88	9.6	8.0
	Muddlers	53	127	58.8	44.8
September 25 and 26 (All methods)	Brook trout:				
	Over 7 inches	4	342	100.0	100.0
	4-6.9 inches	58	1,156	100.0	100.0
	Less than 4 inches	283	1,121	100.0	100.0
	Muddlers	90	284	100.0	100.0
Total		435	2,903	100.0	100.0
Brook trout removed by seining		317	2,520	91.9	96.2
Brook trout removed by poisoning		28	99	8.1	3.8
All fish removed by seining		354	2,677	81.4	92.8
All fish removed by poisoning		81	226	18.6	7.8

Table 4.—Analysis of difficulty of capture of the fish population of Diversion II-A, September 25 and 26, 1940

Date and method and time of capture	Item	Total number	Total weight (grams)	Percentage of Total number	Percentage of Total weight
September 25 (Morning seining)	Brook trout:				
	Over 7 inches	5	387	50.0	52.0
	4-6.9 inches	35	713	44.3	44.6
	Less than 4 inches	102	395	59.6	60.7
	Muddlers	3	17	3.1	5.8
September 25 (Afternoon seining)	Brook trout:				
	Over 7 inches	5	356	50.0	48.0
	4-6.9 inches	32	662	40.5	41.5
	Less than 4 inches	45	174	26.3	26.8
	Muddlers	23	63	23.4	21.7
September 26 (Poisoning)	Brook trout:				
	Over 7 inches	....	....	0.0	0.0
	4-6.9 inches	12	222	15.5	13.9
	Less than 4 inches	24	81	14.1	12.5
	Muddlers	72	211	73.5	72.5
September 25 and 26 (All methods)	Brook trout:				
	Over 7 inches	10	743	100.0	100.0
	4-6.9 inches	79	1,597	100.0	100.0
	Less than 4 inches	171	650	100.0	100.0
	Muddlers	98	291	100.0	100.0
Total		358	3,281	100.0	100.0
Brook trout removed by seining		224	2,687	86.2	89.9
Brook trout removed by poisoning		36	303	13.8	10.1
All fish removed by seining		260	2,767	72.6	84.3
All fish removed by poisoning		98	514	27.4	15.7

by poison. The percentage of all fish taken was 72.6 by seining and 27.4 by poison.

To demonstrate further how much error would be introduced by considering results obtained by seining only, the percentage of the weights removed from the two sections by seining and by poisoning are shown in Table 3 and 4. For example, seining alone accounted for only 84.3 per cent of the total weight of fish taken from II-A. Seining appears to have been more efficient in III-A, where nearly 93 per cent of the total weight of fish captured was taken by this method.

On the basis of the percentage of brook trout removed by seining, II-A might be classed as "moderately difficult to seine," and III-A as "easy to seine," if data obtained by Trippensee (1937) on New Hampshire trout streams are applicable to Michigan trout waters.

The discrepancies that can be noted in Tables 3 and 4 between the populations found by seining, and those found by seining plus poisoning, present further proof that seining alone cannot remove all the fish from even a small area of stream unless conditions are extremely favorable. These conditions (such as gently sloping shore, smooth bottom with no rocks or snags, gentle current, etc.) seldom occur in normal trout streams. It should be remembered, too, that the seining discussed here was conducted with a water level so low as to almost isolate the deeper pools, and that there was no interference in the seining

operations from the water currents. Had the water level and current been normal, we probably could not have taken as many fish by seining as are shown in the tables.

Age and Growth of the Brook Trout

From the 605 brook trout that made up the total population of the two blocked-off areas, a series of scale samples from 95 individuals were studied. This series was augmented further by the scales of 27 brook trout collected from the same general stream area in the course of the September seining of the experimental stream for marked brook trout. The growth history of the brook trout in Section C was computed from scale measurements of 71 wild fish of the 122 fish whose ages were determined. All scales (except for 33 small trout of age group 0 and 19 from I group) were mounted on microscope slides in glycerin-gelatin and studied on the microprojection machine at the magnification X 90. Scales of the fish for which slides were not made were examined under water by means of a binocular microscope or on the microprojector. Scales of these fish were examined to determine as closely as possible the upper and lower limits of the size ranges of age groups 0 and I respectively.

The data relating to age and growth suggest that the brook trout on the upper reaches of Hunt Creek are relatively slow-growing. From Table 5 and Figure 3 it will be noted that the average calculated total length of brook trout in this stream does not reach the legal limit of 7 inches until sometime during the fourth summer of life (age group III). According to the length measurements and growth calculations from scale measurements, the average total length of the wild brook trout in Section C at the end of 1 year is slightly more than 3 inches;

Table 5.—Actual and calculated total lengths (inches) of wild brook trout in Section C of Hunt Creek, September 24-26, 1940

Age-group	Number of scales studied	Average total length at capture	Average calculated total length of fish at end of year of life			Range in total length at capture
			1	2	3	
I	44[1]	4.06	3.03	....	....	2.80-5.83
II	37	6.34	3.07	5.08	....	4.72-8.58
III	9	7.99	2.87	4.76	6.81	6.61-9.45
Total or average	90	....	3.03	5.00	6.81	2.80-9.45

[1]Measurements were made on scales of only 25 fish of this age group.

at the end of 2 years, 5 inches; at the end of 3 years, just under 6⅞ inches; at the end of 3¾ years, 8 inches. (The average total length of 9 fish showing three annuli at the time of the population study was 8 inches.)

The average total length of the young of the year (spawned the previous fall and showing no annuli on their scales) was 68 millimeters (about 2⅝ inches). The size range of the fish in age group 0 was from

57 to 81 millimeters (about 2¼-3¼ inches, total length). An overlap in the size ranges of the several age groups was noted (Table 5 and Figure 3). The length of brook tout in age-goup I ranged from 2¾ to 5⅞ inches; those in age group II was found to vary from 4¾ to 8⅝ inches; and fish in the oldest age group, III, was found to range from 6⅝ inches to 9½ inches. Such an overlap in the size ranges of the various age groups makes it impossible to predict accurately the ages of the various elements of the brook trout population from their total lengths.

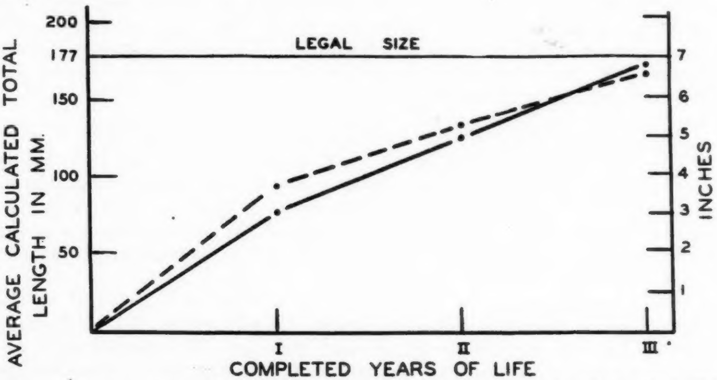

FIGURE 3.—Average calculated total lengths of Hunt Creek brook trout (solid line), and New York State brook trout (broken line) at the end of various years of life

Although the growth curve drawn up from the average calculated total lengths at the end of the various years of life indicates that the brook trout from this part of Hunt Creek do not reach legal size until sometime during their fourth summer of life, actually a small portion of the population does exceed the size of 7 inches, total length, during the third summer (age group II). At the same time it should be pointed out that not all of the fish found to be in their fourth summer of life (age group III) were of legal size. Since the population study was conducted shortly after the close of the 1940 trout season, it is very possible that the anglers' catch reduced the number and the average size of the brook trout recorded in age-groups II and III, as the law permits the angler to keep only those fish taken by hook and line which are 7 inches or longer.

Some comparative data on the age and growth of brook trout in 13 trout streams in New York state are given by Hazzard (1932). In this study it was found that the average calculated total lengths were: at the first annulus, slightly less than 3¾ inches; at the second annulus, slightly less than 5⅜ inches; at the third annulus, 6⅝ inches.

Apparently the brook trout in those New York streams grew at a slightly faster rate during the first 2 years of life than did the brook trout of Hunt Creek, but exhibited a diminished rate of growth during the third year. The growth curve for the New York fish is presented also on Figure 3.

Comparisons were also made of the average total length of brook trout of various ages from three other Michigan brook trout waters (unpublished data) and with the data presented by Ricker (1932) for the growth of Ontario brook trout. Without going into detail here it may be said that the Hunt Creek brook trout grow the most slowly of brook trout in any of the waters on which data are available. The comparative data suggest that the length of 7 inches is reached in the other streams for which comparative data are available during the third instead of in the fourth summer of life.

Age Composition of the Brook Trout Population

The distribution of the brook trout population among the various age groups is of considerable interest. If it is assumed that the sample of fish which was studied for ages is representative, the percentage of the total population of wild brook trout of the two diversions in the various age groups may be calculated from the percentages obtained from a study of the scale samples.

Table 6 presents the number and percentage of fish found in the various size ranges (7 inches or larger, 4.0-6.9 inches, 2.1-3.9 inches) for the fish whose scales were studied for age. The percentages obtained were then applied to the known length-frequency distribution (Table 2) to calculate the total number of wild fish of the several ages in the various size ranges (Table 7).

Table 6.—Age and size distribution among 95 wild brook trout from Diversions II-A and III-A, Section C, Hunt Creek, September 25, 26, 1940

Size range (inches)	Number of wild brook trout whose ages were determined	Number (and percentage) of brook trout in sample in each size group			
		0	I	II	III
2.1-3.9	52	33 (63.5)	19 (36.5)	....	....
4.0-6.9	29	....	5 (17.0)	23 (79.0)	1 (4.0)
7.0-9.5	14	....	....	5 (35.7)	9 (64.3)

Table 7.—Distribution of the various age groups of the wild brook trout population of Diversions II-A and III-A, Section C, of Hunt Creek (as determined from the data presented in Table 6)

Size range (inches)	Actual number of wild brook trout in size range	Calculated number of wild brook trout in age group				Total
		0	I	II	III	
2.1-3.9	415	264	151	....	....	415
4.0-6.9	136	....	23	107	6	136
7.0-9.5	14	....	....	5	9	14
Total	565	264	174	112	15	565
Calculated percentage of wild brook trout in each age group		46.7	30.8	19.8	2.7	100.0

Where fish of the same age occurred in more than one size range, the sum for the group was determined. The percentage of the total population of wild fish (565) in the age groups was found by dividing the number in each age-group by 565. According to this latter calculation, 46.7 per cent of the wild brook trout population were young of the year (no annulus on the scale), 30.8 per cent were 2 summers old (one annulus), 19.8 per cent were 3 summers old (two annuli), and 2.7 per cent were 4 summers old (three annuli).

If it is assumed that the population count in II-A plus III-A is representative of Section C of Hunt Creek, the age composition of the wild brook trout population of Section C in September, 1940, would be as follows: age group 0—2,155 fish; age group I—1,421 fish; age group II—914 fish; age group III—125 fish; total population of wild brook trout—4,615 fish (Table 8). The above figures were determined by applying the percentages obtained in Table 8 to the calculated number of wild fish per acre as shown in Table 1, and then multiplying the results by 1.07, the measured water acreage of Section C of Hunt Creek.

It is of interest to note that if the calculated population of wild fish of legal size (114) is correct, the 1940 anglers' catch was approximately 50 per cent of the standing crop of legal-sized brook trout, since the intensive creel-census records for Section C in 1940 show a catch of 113 legal brook trout.

Table 8.—Calculated age and size distribution of the wild brook trout in the total estimated population of Section C (area 1.07 acres) of Hunt Creek, September 25-26, 1940, with an estimate of the percentage of survival from age group to age group. (Figures in parentheses indicate the percentage of each age group in each size range)

Item	Age group				Total
	0	I	II	III	
Calculated number of wild brook trout in size range 2.1-3.9 inches	2,155 (100.0)	1,233 (86.8)	....	....	3,388 (73.4)
Calculated number of wild brook trout in size range 4.0-6.9 inches	....	188 (13.2)	875 (95.7)	46 (36.9)	1,109 (24.0)
Calculated number of wild brook trout in size range 7.0-9.5 inches	....	....	39 (4.3)	79 (63.1)	118 (2.6)
Distribution of calculated total brook trout population of Section C among the age groups	2,155	1,421	914	125	4,615
Percentage of wild brook trout surviving from previous age group	100.0	65.9	64.3	13.7	....
Calculated survival from 1,000 young-of-the-year brook trout	1,000	659	424	58	....

Percentage of Fish Surviving from One Age Group to the Next

From the data available through the calculations demonstrated in Tables 6, 7, and 8, the percentage of the calculated total population of Section C in the various size ranges and age groups were estimated. The number of fish surviving from one age group to the next may be

regarded as an index of mortality from year to year, if it is assumed that the factors causing mortality between the several age groups are the same from one year to another. The survival was found to be: 65.9 per cent between the first and second summers; 64.3 per cent between the second and third summers; 13.7 per cent between the third and fourth summers (Table 8). The number of fish surviving to the end of the various years of life from 1,000 young of the year would then be: second year, 659 (all undersized); third year, 424 (18 or 4.3 per cent of legal size); fourth year, 58 (36 or 63.1 per cent of legal size). In other words in Section C of Hunt Creek only 54 (36 plus 18) or 5.4 per cent of the brook trout out of 1,000 fingerlings reach the legal size of 7 inches, total length, by the end of the fourth summer of life. If the creel-census figures for Section C for the 1940 season indicate the true situation, the angler takes only about 50 per cent of the legal trout present and the return to him per 1,000 fingerlings would be in the neighborhood of 2.7 per cent, or approximately 27 legal fish out of every 1,000 young-of-the-year brook trout available in the late summer. Probably the most important function of the Hunt Creek Fisheries Experiment Station will be to determine the fate of the other 97.3 per cent and whether a greater return to the angler can be effected in any practicable way.

Coefficient of Condition of Brook Trout in Section C, Hunt Creek

Knowledge concerning the condition of the brook trout, that is, whether the fish are heavy or light for their respective lengths, is of interest in connection with their rate of growth. Since measurements and weights were available from 144 specimens of the population, the coefficient of condition (K) was calculated for these fish. This series of coefficients is almost entirely for brook trout exceeding 100 millimeters, total length (approximately 4 inches). Neither time nor facilities for the accurate weighing of fingerling fish were available during the population study.

The coefficient of condition (K) was calculated from the formula

$$K = \frac{\text{weight in grams} \times 100{,}000}{(\text{standard length in millimeters})^3}$$

The average K for the 144 specimens (size range 98-240 millimeters total length) was found to be 1.469, and the K values ranged from 0.970 to 2.029 (Table 9).

The brook trout for which coefficients of condition were determined were separated into 10-millimeter size groupings starting at 90 millimeters and running to 249 millimeters. The average K for each group was determined and plotted against the average total length (Table 9 and Figure 4). The table and chart appear to demonstrate that the larger fish were in better condition (were heavier for their lengths)

Table 9.—Summary of data on the coefficient of condition of wild brook trout population of Diversions II-A and III-A, Section C, Hunt Creek, September 25 and 26, 1940

Range in total length, (millimeters)	Number of specimens in group	Range in coefficient of condition	Average K
90- 99	1	1.270	1.270
100-109	14	1.135-1.729	1.340
110-119	33	1.205-1.686	1.413
120-129	21	0.970-1.700	1.410
130-139	24	1.158-2.029	1.471
140-149	13	1.206-1.826	1.479
150-159	12	1.331-1.806	1.566
160-169	8	1.385-1.891	1.679
170-179	7	1.285-1.799	1.547
180-189	3	1.480-1.731	1.564
190-199	2	1.497-1.593	1.545
200-209	1	1.771	1.771
210-219	4	1.577-1.726	1.643
220-229	....	....	....
230-239	....	....	....
240-249	1	1.672	1.672
Total or average	144	0.970-2.029	1.469

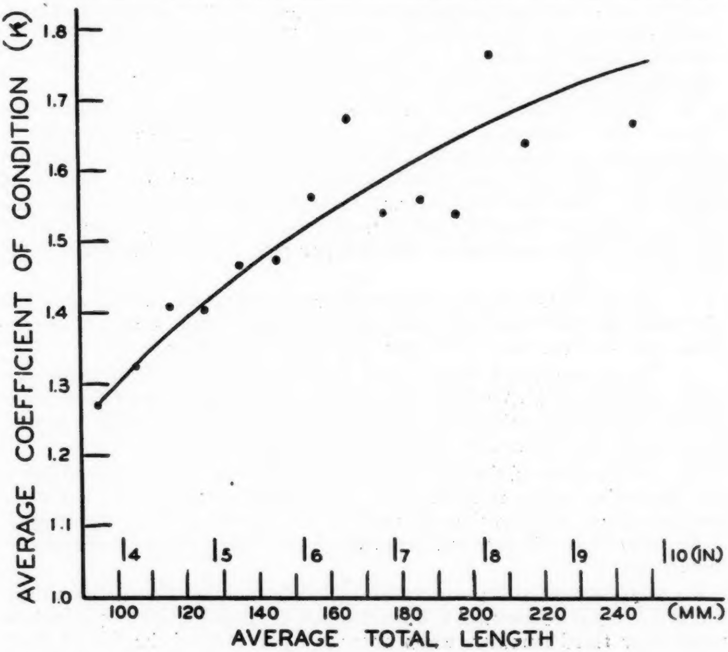

FIGURE 4.—Relationship between average total length and average coefficient of condition of brook trout in II-A and III-A, Section C, Hunt Creek, Montmorency County, Michigan, September, 1940

than were the smaller fish. The larger brook trout, particularly those above 150 millimeters, total length (approximately 6 inches), were approaching sexual maturity, or were sexually mature and preparing for the spawning season, which fact may explain partially the somewhat higher average values obtained for the larger fish.

The average values of *K* found for the Hunt Creek brook trout are somewhat higher than the values of *K* published by Hazzard (1932) for 18 New York trout streams, and by Klak (1941) for three West Virginia trout streams. Since live weights were taken in this study and dead weights (after several hours in the creel) were used by these other workers, a loss of weight subsequent to capture may at least partially account for the higher average condition of trout in Hunt Creek.

Summary

1. The conditions which made possible the study and the methods used to carry out an exact population count of 580.5 feet of Section C of Hunt Creek in Montmorency County, Michigan, were described. To the best of our knowledge, the figures obtained represent a 100 per cent capture of the fish present in the blocked-off area.

2. A total population of 605 brook trout and 188 muddlers was found. The calculated numbers of trout and muddlers per acre of stream were determined to be 4,619 and 1,435 respectively; the weights in pounds per acre were 94.40 pounds of trout and 9.68 pounds of muddlers. Hatchery-reared trout, recognizable by the combinations of fins which had been clipped at their release, made up 6.7 per cent of the actual trout population and 2.7 per cent of the calculated total weight of trout.

3. Of the total number of brook trout captured (605), some 2.3 per cent were of legal size, 22.0 per cent were from 4 to 6⅞ inches long, and 75.7 per cent were from 2⅛ to 4 inches long.

4. More legal-sized brook trout and brook trout of sublegal size were taken from II-A where the pools were slightly deeper than from III-A, which was relatively shallow. However, more small (fingerling) trout were found in III-A than in II-A.

5. An analysis of the difficulty with which fish were captured from the blocked-off areas indicates that population studies conducted with the use of the seine as the sole method of capture cannot be expected to be more than 80 per cent accurate, even under the most favorable conditions.

6. Age determinations on a series of scale samples demonstrate that the brook trout of Section C do not reach the legal length of 7 inches until their third summer, when about 4.4 per cent of the fish of that age are longer than 7 inches, total length. About 63 per cent of the 4-summer-old brook trout had reached the legal size of 7 inches, total length.

7. The calculated percentage distribution of the brook trout population of Section C of Hunt Creek among the various age groups was as follows: age group 0, 46.7 per cent; age group I, 30.8 per cent; age group II, 19.8 per cent; age group III, 2.7 per cent.

8. Data on the coefficient of condition (K) for the brook trout of Section C of Hunt Creek demonstrate that the fish were rather heavy for their length, since the average values obtained were somewhat higher than K values published by other authors for brook trout. The high values obtained may have been somewhat influenced by the approach of the spawning season.

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Literature Cited

Embody, G. C.
1929. Stocking policy for the streams, lakes, and ponds of the Erie-Niagara watershed, exclusive of Lake Erie. A Biol. Survey of the Erie-Niagara System. Suppl. to the eighteenth Ann. Rep., State of New York, Cons. Dept., 1928, pp. 23-24.

Hazzard, A. S.
1932. Some phases of the life history of the eastern brook trout, *Salvelinus fontinalis* Mitchell. Am. Fish. Soc., Vol. 62, pp. 344-350.

Klak, George E.
1941. The condition of brook trout and rainbow trout from four eastern streams. Trans. Am. Fish. Soc., Vol. 70 (1940), pp. 282-289.

Ricker, William E.
1932. Studies of speckled trout (*Salvelinus fontinalis*) in Ontario. Univ. of Toronto Studies, Biol. Series, No. 36, Publ. of the Ont. Fish. Research Lab., No. 44, pp. 69-110.

Trippensee, R. E.
1937. Fish population studies on some New Hampshire trout streams. Biol. Survey of the Androscoggin, Saco, and Coastal Watersheds. New Hampshire Fish and Game Dept., Survey Rept. No. 2, pp. 119-124.

A PRE-IMPOUNDMENT BOTTOM-FAUNA STUDY OF WATTS BAR RESERVOIR AREA (TENNESSEE)[1]

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Abstract

Pre-impoundment bottom-fauna data are presented for the Watts Bar Reservoir area (Tennessee). A salting-out technique is described which was used to facilitate the separation of organisms from debris. In deep water four major taxonomic groups made up 98.93 per cent of the total number and practically 100 per cent of the total volume. Nymphs of *Hexagenia bilineata* (Say) composed 82.43 per cent of the total volume. This species probably has a 1-year life cycle in Tennessee. Production was highest on the muddy bottom and lowest on sand. Data on depth distribution showed the first 10 feet to be most productive. The seasonal peak of production was reached during September and October. This maximum was due almost entirely to mayflies. The rate of growth of *Hexagenia* nymphs was most rapid during August and September or immediately following hatching. The riffles and flats at the shallow-water station were less productive than the mud-sand bottom of the deep water. The fauna of the riffles and flats will probably not survive impoundment; however, the fauna of the deep-water area will survive.

Introduction

A series of studies aimed at learning what changes occur in basic fertility, fish food, fish population, and fishing with transformation of the Tennessee River and many of its tributaries from streams to reservoirs is being conducted. The present study was undertaken to determine the relative amount of bottom fauna potentially available for fish food prior to impoundment in that portion of the original river channel now included by Watts Bar Reservoir. A concurrent bottom-fauna study was made in the original river channel of that part of the Holston River which is now flooded by Cherokee Reservoir. Cherokee is a storage reservoir and Watts Bar is a run-of-the-river reservoir; the two types differ decidedly as habitats for fish and fish food. A comparison of the bottom fauna in the two reservoir areas before and after impoundment is planned.

Watts Bar Reservoir (Table 1) is located on the Tennessee River 530 miles above the mouth, between Chickamauga and Fort Loudoun Reservoirs. It is the second of a series of nine reservoirs which impound the entire length of the Tennessee River from its source to within about 20 miles of its mouth (Ohio River).

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Table 1.—Morphometric data on Watts Bar Reservoir, Tennessee. All elevations are in feet above sea level. (Data from Watts Bar Project, T.V.A. Water Control Planning Department, December 1938.)

Original river area (acres)	10,700
Reservoir:	
Area (acres)	
maximum, at elevation 745	41,500
minimum, at elevation 735	32,200
Length (miles)	72.4
Shoreline (miles) normal pool at elevation 741	543.0
Average width (miles) at elevation 741	0.82

ing technique; and to Alden M. Jones for aid in collecting and sorting samples.

Stations

Station I, for deep-water (1-30 feet) samples, was chosen near the center of the reservoir area just below Long Island between miles 569 and 570. In this area the bottom was composed primarily of mud and sand. The mud and sand bottom was the predominant type of habitat along the channel of the Tennessee River in the Watts Bar Reservoir area. In this type of habitat, current, except during periods of flood, was for the most part negligible. The bottom was arbitrarily classified as either mud, sand, muddy sand (sand predominating), or sandy mud (mud predominating).

Station II, for shallow-water (2-18 inches) samples, was selected in the same general locality near the upper end of Ebben Island which was located to the left and approximately 1 mile above the lower end of Long Island. In this area the water flowed over a bottom consisting of rocks and gravel. Here the current was relatively strong and in certain places produced riffles. For this reason samples were collected from an area where the water surface was classified as flat or riffled. Whether or not the surface of the water is flat or riffled depends upon some combination of the following factors: character of bottom surface, slope of bottom, size of stones, depth of water, and rate of current.

Methods

Collecting at Station I was accomplished with an unweighted Petersen dredge which covered an area of 0.82 square feet. Within the station area samples were taken at random from various depths and kinds of bottom. Usually three hauls comprised one sample from any given depth. The range of depth for all samples taken was 1.5-30.0 feet. A 30-mesh screen was used in the field for washing and concentrating samples. The residue, including the organisms, was preserved with 10 per cent formalin.

In the rocky to gravelly shallow area at Station II, where a relatively strong current was present and where use of a Petersen dredge was impracticable, a Surber sampler (Surber, 1937) with a 24-mesh cloth screen bag was used. This sampler was designed to cover an area of 1 square foot. The washed residue was preserved with 10 per

cent formalin. The depth range for these samples was 2 to 18 inches.

A total of 228 bottom samples was secured, 122 from Station I and 106 from Station II. Sampling was done from July to December 1941 (for exact dates see Fig. 1).

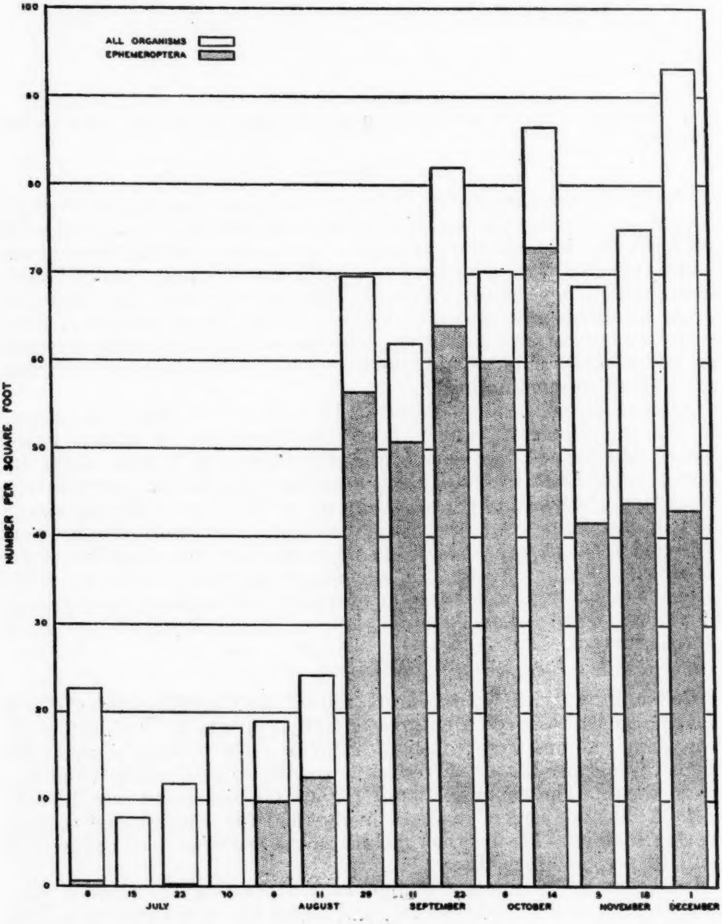

Figure 1.—Seasonal distribution (1941) at Station I, Tennessee River, Watts Bar Reservoir area, Tennessee, of all organisms as compared with the Ephemeroptera on the basis of numbers.

In order to separate the organisms from the debris, a technique involving the use of a saturated salt (NaCl) solution was used in the laboratory to concentrate the organisms further before finally picking the sample. The preserved field residue was placed in a screen and thoroughly rewashed. If no large stones or other bulky debris were present in the sample the salting-out process proceeded immediately from this point. However, if numerous large stones or other bulky debris were present, the sample was washed into a large pan which in turn was placed in the screen. A strong stream of water was used to agitate and wash out of the pan all of the lighter-weight material which included most of the organisms, thus leaving behind only the heavier residue. This coarse residue could then be examined quickly for stray organisms. Seldom were any found. That material which had been washed into the screen was then transferred to a pan and the excess water, required to wash off the screen, was poured through a screen cup to catch any floating organisms. The residue caught by the screen cup was later added to the main residue of concentrated organisms obtained by salting. The drained residue left in the pan was flooded with a saturated salt solution and stirred vigorously. This stirring caused most of the organisms to float to the surface. The salt solution, carrying with it the floating organisms, was poured into a funnel covered by grit cloth of proper mesh to retain all specimens. Alternate flooding with the salt solution and floating off the organisms was repeated on the residue until no more could be secured. Three to five times was usually sufficient. The salted residue was examined for any organisms that had not floated out. The organisms in the concentrated residue on the funnel were then separated from the small amount of debris which had floated over with them.

At times the routine method had to be modified slightly to meet the circumstances. For example, when masses of filamentous algae occurred in the sample, many organisms became entangled and could be obtained only by hand picking. The salting method not only shortened the total time involved, but it undoubtedly reduced the number of smaller organisms inevitably missed by ordinary hand picking.

All specimens were finelly sorted to major taxonomic groups and counted; the volume of each group was measured by displacement in alcohol. Various volumetric measuring devices were used according to the size and number of organisms to be measured. Centrifuge tubes of assorted sizes graduated to 0.01 or 0.1 cubic centimeters were found convenient for the determination of the smaller volumes, and cylinders graduated to 0.1 or 1.0 cubic centimeters were used to determine larger volumes. The numbers given for the Oligochaeta are only approximations, since many of the smaller specimens became fragmented and could be counted accurately; however, volume measurements for this group are reliable. All specimens were placed on an absorbent paper to remove excess moisture before they were measured for volume.

Abundance of Major Taxonomic Groups

In the deep-water samples taken at Station I, 12 principal taxonomic groups[2] were represented (Table 2). Of these 12 groups, 4 (Ephemeroptera, Diptera, Oligochaeta, Anisoptera) made up 98.93 per cent of the total number. These same four groups comprised for all practical purposes 100 per cent of the total volume since all other groups were represented by immeasurable traces.

Table 2.—Average numbers and volumes (cubic centimeters) per square foot of bottom organisms at Station I, Tennessee River, Watts Bar Reservoir area, Tennessee. Based on 122 bottom samples (average of 2.9 hauls per sample) taken in deep water with a Petersen dredge, 1941

Organisms	Number	Percentage of total number	Volume	Percentage of total volume
Nematoda (Roundworms)	0.07	0.14	Trace	Trace
Oligochaeta (Earthworms)	7.01	13.86	0.08	10.81
Hirudinea (Leeches)	0.01	0.02	Trace	Trace
Decapoda (Crayfish)	Trace	Trace	Trace	Trace
Hydracarina (Water mites)	0.04	0.08	Trace	Trace
Sialidae (Alder flies)	0.01	0.02	Trace	Trace
Ephemeroptera (Mayflies)	32.42	64.10	0.61	82.43
Anisoptera (Dragonflies)	0.78	1.54	0.04	5.41
Zygoptera (Damselflies)	0.01	0.02	Trace	Trace
Coleoptera (Beetles)	0.30	0.59	Trace	Trace
Trichoptera (Caddisflies)	0.10	0.20	Trace	Trace
Diptera (True flies)	9.83	19.43	0.01	1.35
Total	50.58	100.00	0.74	100.00

In the shallow-water samples from Station II, 12 major taxonomic groups (Table 3) were also present with only minor differences in the groups represented as compared with the deep-water fauna of Station I. The Hirudinea and Hydracarina at Station I were not present in the Station II fauna; likewise, the Turbellaria and Plecoptera of the Station II samples were not found among the Station I fauna. Of the 12 groups, 4 (Ephemeroptera, Trichoptera, Diptera, Oligochaeta) made up 86.27 per cent of the total numbers. Four of the groups (Oligochaeta, Sialidae, Decapoda, Ephemeroptera) comprised 90.24 per cent of the total volume. It may be noted that while Trichoptera and Diptera were significant as to numbers, the Sialidae and Decapoda were more important from the standpoint of volume. Likewise, the Ephemeroptera which composed 33.61 per cent of the total numbers of all organisms, formed only 4.88 per cent of the total volume. This group was not as important at Station II as it was at Station I. However, these facts may be viewed from a different angle with regard to their importance in the light of available fish food. It would seem that smaller fish would be benefited more by the large number of small organisms, whereas, only the larger fish would be benefited by the small number of larger organisms.

Although the higher taxonomic categories, such as, family, order,

[2]Exclusive of the Mollusca.

Table 3.—Average numbers and volumes (cubic centimeters) per square foot of bottom organisms at Station II, Tennessee River, Watts Bar Reservoir area, Tennessee. Based on 106 square-foot bottom samples taken in shallow water with a Surber sampler, 1941

Organisms	Number	Percentage of total number	Volume	Percentage of total volume
Turbellaria (Flatworms)	0.20	0.45	Trace	Trace
Nematoda (Roundworms)	0.62	1.39	Trace	Trace
Oligochaeta (Earthworms)	5.79	12.98	0.15	36.59
Decapoda (Crayfish)	0.03	0.07	0.07	17.07
Sialidae (Dobson-flies)	1.04	2.33	0.13	31.70
Ephemeroptera (Mayflies)	15.00	33.61	0.02	4.88
Anisoptera (Dragonflies)	0.38	0.85	0.01	2.44
Zygoptera (Damselflies)	1.34	3.01	0.01	2.44
Plecoptera (Stoneflies)	0.17	0.38	0.01	2.44
Coleoptera (Beetles)	2.34	5.25	Trace	Trace
Trichoptera (Caddisflies)	9.96	22.33	0.01	2.44
Diptera (True flies)	7.74	17.35	Trace	Trace
Total	44.61	100.00	0.41	100.00

and class may be the same for the two general habitats, it is not to be concluded that the specific or generic groups were identical. For example, the Sialidae in the Station I fauna belonged to the genus *Sialis* while those in the Station II fauna were *Corydalus*. The Ephemeroptera of the Station I fauna were *Hexagenia* while those of Station II habitat belonged to various genera from the families Heptageniidae and Baetidae.

The data (Tables 2 and 3) show that the average number of deep-water organisms (Station I) per square foot was 50.58, with an average volume per square foot of 0.74 cubic centimeters, as compared with an average number of 44.61 and an average volume of 0.41 cubic centimeters for the shallow-water area (Station II).

Distribution on the Bottom

Table 4 shows that of the four types of bottom (mud, sandy mud, muddy sand, and sand) mud was the most productive as to both number and volume. This production can be traced primarily to the abundance of Ephemeroptera in both number and volume since this

Table 4.—Abundance of bottom organisms per square foot and average size of organisms on four types of bottom at Station I, Tennessee River, Watts Bar Reservoir area, Tennessee. Based on 122 bottom samples (average of 2.9 hauls per sample) taken in deep water with a Petersen dredge between July and December, 1941. Volume in cubic centimeters.

Item	Mud (60 samples)		Sandy mud (26 samples)		Muddy sand (21 samples)		Sand (15 samples)	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume
All organisms	81.91	1.60	38.84	0.36	32.82	0.22	7.86	0.03
Ephemeroptera	57.85	1.44	20.89	0.22	19.24	0.12	2.06	0.01
Average size, exclusive of mayflies	....	0.007	....	0.008	....	0.007	....	0.004
Average size of mayflies	....	0.025	....	0.011	....	0.006	....	0.005

group formed between 53 and 70 per cent of the total number and between 54 and 90 per cent of the total volume of all organisms on all types of bottom except sand.

A study of the distribution of forms with relation to depth (Table 5) shows that the first 10 feet are the most productive in both volume and number. This region produced over 64 per cent of the total number and over 80 per cent of the total volume found at all depths. It is significant to note that the upper 10 feet of bottom is the area most affected by changes in water level.

A comparison of productiveness of the flats and riffles at Station II is shown in Table 6. Riffles were somewhat more productive in number and volume.

Table 5.—Average numbers and volumes (cubic centimeters) per square foot of bottom organisms according to depth at Station I, Tennessee River, Watts Bar area, Tennessee.

[Based on 122 bottom samples (average of 2.9 hauls per sample) taken in deep water with a Petersen dredge, 1941]

Depth	Number of samples	Number	Volume
1-5	25	76.87	1.50
6-10	40	78.80	1.43
11-15	33	38.44	0.39
16-20	15	20.78	0.16
21-25	6	11.25	0.05
26-30	3	16.26	0.06

Table 6.—Abundance of bottom organisms per square foot on riffles and flats at Station II, Tennessee River, Watts Bar Reservoir area, Tennessee. Based on 106 square-foot bottom samples taken in shallow water with a Surber sampler, 1941.

[Volume in cubic centimenters.]

Riffle (46 samples)		Flat (60 samples)	
Number	Volume	Number	Volume
54.28	0.44	35.18	0.37

Seasonal Distribution

The numbers and volumes of the fauna at Station I were low during early summer and gradually became higher in late summer (Figs. 1 and 2). The importance of mayflies as a component of this fauna is clearly shown by the graphs. The maximum number of Ephemeroptera was present during September and October (Table 7). The reason for the distinct decline in November is not apparent. However, the total number of all organisms was maintained more or less constant during November and December due to the increase in the number of organisms other than mayflies. Figure 2 shows that mayflies play an even more important role from the standpoint of volume. Over the 6-month period from July to December no very consistent change occurred in that portion of the volume made up of organisms other than mayflies (Table 7). During July and August the volume of mayflies was very low or nil. This scarcity was caused by the early-summer

Table 7.—Seasonal distribution of bottom organisms in average numbers and volumes (cubic centimeters) per square foot at Station I in the Watts Bar Reservoir area of one Tennessee River, 1941.

[Based on 122 bottom samples (average of 2.9 hauls per sample) taken in deep water with a Petersen dredge. T=trace.]

Date	Ephemeroptera		Other organisms		Total	
	Number	Volume	Number	Volume	Number	Volume
July 8	0.52	T	21.89	0.17	22.41	0.17
July 15	....	....	7.86	0.04	7.86	0.04
July 23	0.20	T	11.41	0.12	11.61	0.12
July 30	....	....	18.04	0.20	18.04	0.20
August 6	9.84	0.03	8.99	0.10	18.83	0.13
August 11	12.43	0.05	11.64	0.12	24.07	0.17
August 29	56.20	0.61	13.39	0.09	69.59	0.70
September 11	50.58	0.86	11.12	0.13	61.70	0.99
September 23	63.82	1.22	17.79	0.13	81.61	1.35
October 6	59.89	1.42	10.11	0.08	70.00	1.50
October 14	72.67	2.10	13.88	0.09	86.55	2.19
November 5	41.42	1.06	26.93	0.15	68.35	1.21
November 18	43.59	1.15	31.08	0.18	74.67	1.33
December 1	42.71	1.00	50.35	0.21	93.06	1.21

emergence of this group. In late August the eggs laid earlier began to hatch so that from this time on the volume due to mayflies became increasingly important and reached a maximum in October. Corresponding with the drop in numbers (Fig. 1), the volume was reduced by about one half in November. This level would probably be maintained throughout the winter with some increase in late spring due to growth just before emergence.

It appears that the length of the life cycle of the mayfly, *Hexagenia bilineata* (Say), at least in the Tennessee area, is 1 year rather than 2 years. Needham (1920) concluded that this species has a 2-year cycle in the northern reaches of the Mississippi River. Certain other species of *Hexagenia* in the region of the Great Lakes have a 2-year life cycle (Lyman, 1940, MS.). If *Hexagenia bilineata* had a 2-year cycle in Tennessee, specimens should have been present in greater numbers during July and August. There should also have been two distinct size and age groups present during September; only one group was found. The increase in volume and number (Table 7) that occurred in late summer and early fall was evidently due entirely to hatching of eggs and growth of the young nymphs.

The rate of growth of *Hexagenia* nymphs (Fig. 3) was most rapid during August and September or immediately following hatching. (Growth has been expressed in terms of the number of individuals per cubic centimeter, computed from data given in Table 7.) Growth was greatest on mud or sandy mud. Since by far the larger number and volume of mayfly nymphs occurred on the mud and sandy mud bottom, the growth curve represents essentially the rate of growth on these two types of bottom. The average size of an individual nymph on the various types of bottom is shown in Table 4. (From this same table comparisons may be made of the average size of individuals of all other organisms with that of an individual mayfly.) On mud and sandy mud the mayfly nymphs averaged much larger than on the

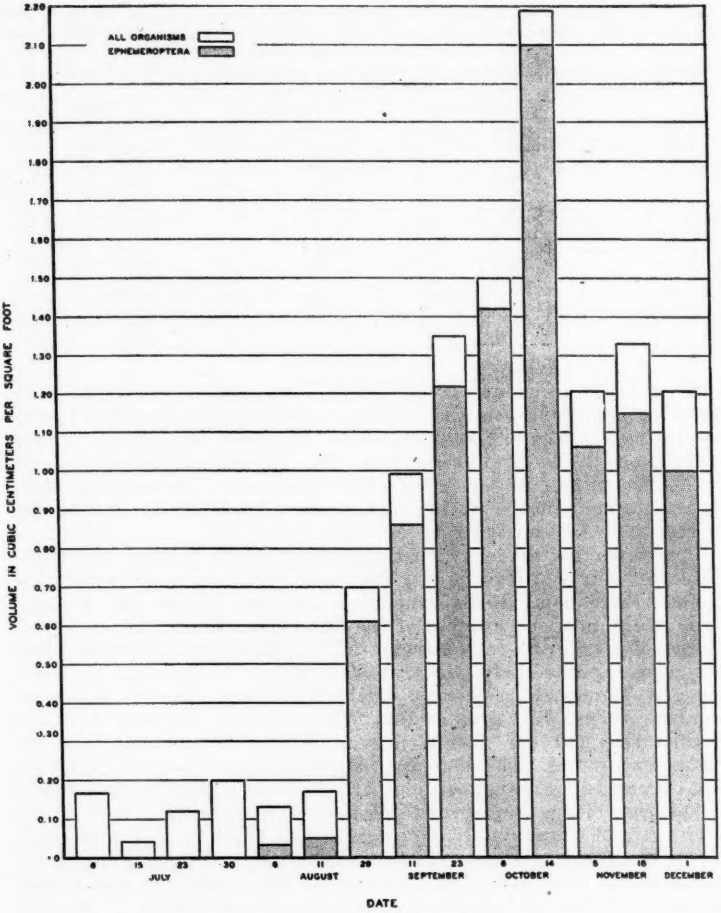

FIGURE 2.—Seasonal distribution (1941) at Station I, Tennessee River, Watts Bar Reservoir area, Tennessee, of all organisms as compared with the Ephemeroptera on the basis of volumes.

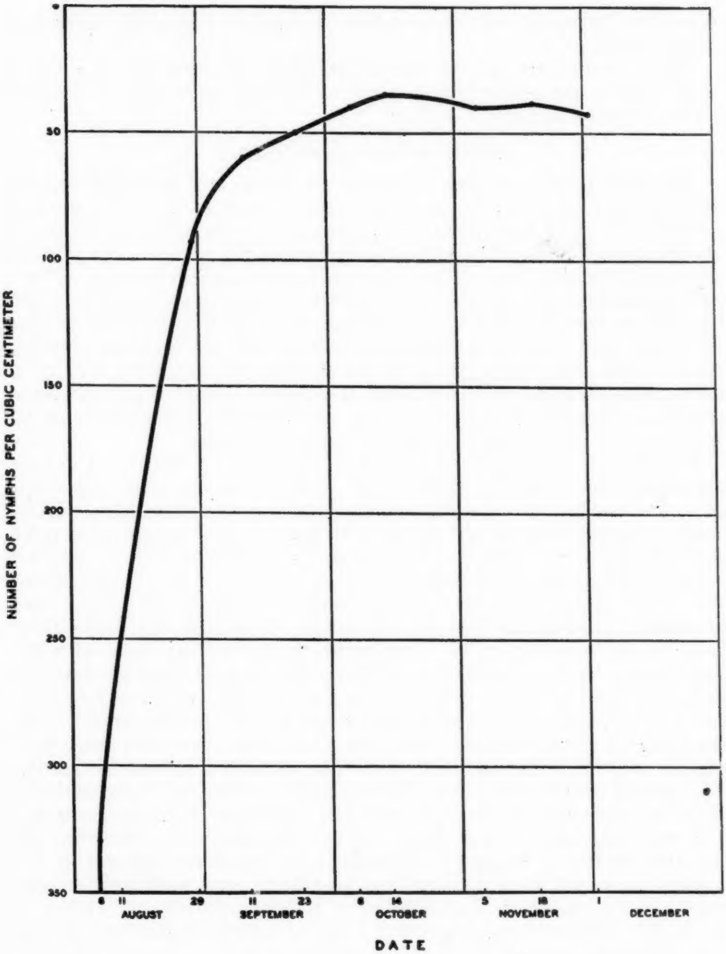

FIGURE 3.—Growth rate of *Hexagenia bilineata* (Say) nymphs averaged from all types of bottom as shown by number required to produce a volume of one cubic centimeter on various dates between August and December 1941, at Station I, Tennessee River, Watts Bar Reservoir area, Tennessee.

other two types of bottom. On muddy sand and sand the sizes were about equal.

The average size of organisms other than mayflies was smallest on sand, while the other three types of bottom produced individuals about twice as large.

Summary and Conclusions

The most important single component of the bottom fauna was the *Hexagenia bilineata* nymphs which were found to have the greatest growth and to be most abundant in the mud or sandy mud bottom of the Tennessee River. From the data presented it is concluded that the length of the life cycle of this species is one year. The peak volume per square foot for all organisms in the deep water (Station I) was reached in October; the lowest volume occurred in July and August. Mayflies were almost entirely responsible for the volume changes. Since Watts Bar Reservoir is of the run-of-the-river type, it may be stated almost with certainty that *Hexagenia* nymphs will not only survive impoundment but will reach even a greater production under the new and undoubtedly more favorable conditions.

The Station I (deep-water) habitat was more productive of bottom organisms than was the Station II (shallow-water) area, especially as to the volume. It is to be expected that most of the members belonging to the Station II fauna will not survive changes incurred by impoundment (silting in and lack of current). Since, however, most of the original river channel now included by Watts Bar Reservoir was composed of the type of habitat found at Station I, this probable loss in fauna will not be critical. Probably the numbers of many of the members of the deep-water fauna will increase with impoundment since it would seem that the new conditions brought about by impoundment will, at least, not become more unfavorable and it is to be expected that most changes will be for the better. The sandy areas of the original river channel which were the least productive will become covered by mud due to silting in and, therefore, will become more productive. Large shallow areas will be inundated which will increase fertility in general. The water level in the reservoir will fluctuate several feet (10 feet maximum). However, the fauna at Station I withstood even greater water-level changes in the original river and should, therefore, be able to cope with similar conditions in the reservoir. Later inquiries will demonstrate the extent to which the various organisms were able to adjust themselves to the new conditions.

Literature Cited

Needham, J. G.
1920. Burrowing mayflies of our larger lakes and streams. Bull. U. S. Bur. Fish., Vol. 36 (1917-18), pp. 267-292.

Surber, Eugene W.
1937. Rainbow trout and bottom fauna production in one mile of stream. Trans. Am. Fish. Soc., Vol. 66 (1936), pp. 193-202.

PERCENTAGES OF SURVIVAL OF BLUEGILLS (*LEPOMIS MACROCHIRUS*) AND LARGEMOUTH BLACK BASS (*HURO SALMOIDES*) WHEN PLANTED IN NEW PONDS[1]

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ABSTRACT

In contrast to the low percentage of survival to be expected when bluegills and largemouth black bass are planted in streams and old lakes, high percentages are obtained when these fish are planted in new ponds. Survivals of 75 to 100 per cent were obtained when bluegill fingerlings alone were planted in ponds in which food was plentiful. In bluegill bass combinations, survivals of 76 to 85 per cent were obtained for bluegill fingerlings. Percentages of survival for largemouth black bass in bluegill bass combinations were 75 for fingerlings and 80 to 90 for advanced fry. Recognition of the high survivals of these species forms one of the bases for an intelligent stocking program for new ponds.

INTRODUCTION

There are three general types of stocking programs in which the percentage of survival is of significance. The first type occurs in the hatchery where the fry are transferred to nursery or rearing ponds and reared to fingerling size before transplanting. The other two are concerned with the transplanting of fish from the hatchery to streams and lakes and to artificial ponds. For the hatchery, the percentage of survival is the percentage of planted fry that survive to fingerling size in the rearing pond. Ideally, the percentage of survival in natural bodies of water should express the percentage of planted fish that grow to legal size, but this figure usually cannot be determined. As generally used it expresses the percentage of planted fish that are caught, and since wild fish usually are included in the catch, this figure is unknown unless a new species is introduced or the planted fish are marked. The percentage of survival of fish planted in new artificial ponds is the percentage of planted fish that survive to legal size; this percentage has been accurately determined in experimental ponds at this Station.

Many data are available on the percentage of survival of black bass in rearing ponds at the hatchery. Davis (1930) reported survivals of 35 to 40 per cent. Hogan (1933) obtained percentages for largemouth bass varying from 49 to 89 in fertilized rearing ponds, and Meehean (1939) obtained percentages of 68 to 85. Brown's (1940) figures for smallmouth black bass in fertilized rearing ponds ranged from 12 to 77 per cent with an average percentage of survival of 50.

[1]Published with the approval of the Director of the Alabama Agricultural Experiment Station.

Most of the data on the percentage of survival of fish planted in streams and lakes are for trout; few are available for warm-water species. Fry were used in the early days of trout-stream restocking programs but the survivals, in terms of improvement in fishing, were so low as to be negligible. Fingerlings were used later but the results were not always satisfactory. Hayford (1926) reported a survival of less than 1 per cent for fingerlings planted in a stream, and Eschmeyer (1938) obtained survivals of 5 per cent or less from large plantings of fingerlings in several Michigan lakes. Rather high percentages of survival have been obtained in recent years when legal trout were planted. The practice of planting legal-sized fish, however, is expensive, highly artificial, and not adaptable to the warm-water species. Aldrich (1939) gave some data on the percentage of survival of largemouth black bass. He reported an annual catch of approximately 12,500 bass from a lake in which 630,000 fingerlings were planted over a period of 7 years. If natural reproduction had contributed nothing to the catch, the percentage of survival would have been only 14; since the bass spawned in the lake, there was no way of determining accurately the percentage of survival of the bass planted. Meehean (1942) has recently studied the populations of a number of Florida lakes. He poisoned the entire population of each lake and found a total of 12 to 27 largemouth black bass of all sizes per acre. At least three times as many bass were planted 3 years perviously as were recovered which fact indicated a low survival of those planted.

Recent research on pond management has had a profound effect on stocking policies, especially with regard to warm-water species. Most of the fish produced in hatcheries formerly were planted in streams and lakes, whereas in recent years larger and larger percentages are being used for stocking new ponds. As a matter of fact, many hatcheries are finding that their capacities are insufficient to meet the demands for stocking these new areas. Consequently, information as to percentages of survival of fingerlings and fry used to stock new ponds is of importance.

Experiments on the Survival of Bluegills and Largemouth Black Bass

A number of ponds have been used for pond-management experiments at this Station since 1934. Each pond has been stocked with a given number of fish in the spring, given a specific treatment during the season, drained, usually in the fall or winter, and all of the fish counted and weighed. Thus, a considerable amount of data on the survival of fish planted in artificial ponds has been accumulated. These data are discussed in the following paragraphs and are summarized in Table 1.

A series of small ponds was used in a fertilizer experiment in 1936. In order to obtain maximum utilization of the food produced, the ponds were stocked at the abnormally high rate of 13,000 bluegill

fingerlings per acre. When the ponds were drained in the fall, survivals of 76 to 90 per cent were found in the fertilized ponds, but only 29 and 30 per cent in the unfertilized controls. As the result of heavy overstocking, however, none of the fish in this experiment reached legal size and high mortalities occurred in the ponds that were not fertilized. Some of the fertilized ponds were stocked during 1937 and 1938 at one-tenth to one-fifth of the 1936 rate. In these experiments, survivals of 75 to 95 per cent were obtained and the bluegills grew to legal size. Although high survivals were obtained when bluegills were stocked alone, the practice of stocking fish ponds with this species only cannot be recommended. The bluegills may reach legal size by the time they spawn, but, afterwards, competition from young bluegills is so great that the adults cannot grow more and actually may lose weight. The minimum legal-sized bluegill is not large enough to please the sportsman.

Ponds, with areas between 1 and 2 acres, were stocked with bluegill-bass combinations in 1939 and 1940. In 1939, when a fertilized pond was stocked with bluegills and largemouth black bass fingerlings, survivals of 85.3 and 74.8 per cent, respectively, were obtained. In 1940, one fertilized and one unfertilized pond were stocked with bluegill fingerlings and largemouth black bass advanced fry. Since the expected carrying capacities of fertilized and unfertilized ponds were taken into consideration and the ponds were stocked accordingly, comparable percentages of survival were obtained. In addition, somewhat higher percentages of survival for the advanced fry were obtained than had been obtained for the bass fingerlings.

Application to Pond Management

The high percentage of survival for fingerlings and fry planted in new ponds may be surprising to those acquainted with the generally low survival of such fish planted in streams and lakes. The differences are easily explained, however, by the differences between the two environments. Old, established bodies of water usually contain all the fish that they can support. Consequently, small fish planted in such waters either find competition so great that most of them are unable to grow to legal size or are consumed by larger, predacious fish. New ponds, on the other hand, contain few or no fish prior to stocking, and fingerlings or fry planted in them find little or no competition and are in little danger of being consumed.

Fish-culturists charged with stocking new ponds must take the percentage of survival of planted fish into consideration if the ponds that they stock are to give good fishing within a reasonable period of time. If they assume that the percentage of survival in new ponds is low as it is in streams and lakes and overstock accordingly, then the fish cannot reach legal size and poor fishing results. If, on the other hand, they understock the pond with bluegills or bass or both, the pond is likely to be out of balance. Swingle and Smith (1942) reported a

Table 1.—Survival of bluegills and largemouth bass planted in new ponds.

Year	Number of ponds	Area of ponds (acres)	Treatment of ponds	Kind of fish planted	Number planted per acre	Number recovered per acre	Percentage survival
1936	5	1/130	Fertilized	Bluegill fingerlings	13,000	9,880-11,700	76.0-90.0
1936	2	1/130	Unfertilized	Bluegill fingerlings	13,000	3,770-3,900	29.0-30.0
1937	2	1/130	Fertilized	Bluegill fingerlings	1,300	1,300	100.0
1938	2	1/130	Fertilized	Bluegill fingerlings	1,500	1,170-1,430	75.0-91.7
1938	2	1/130	Fertilized	Bluegill fingerlings	2,600	2,470	95.0
1939	1	1 3/10	Fertilized	Bluegill fingerlings Bass fingerlings	1,500 98	1,280 73	85.3 74.8
1940	1	1 8/10	Unfertilized	Bluegill fingerlings Bass advanced fry	400 28	334 23	83.5 82.1
1940	1	1 5/10	Fertilized	Bluegill fingerlings Bass advanced fry	1,500 100	1,150 90	76.6 90.0

method of stocking fertilized ponds that takes cognizance of the expected survival of planted fish and that gives good fishing within a year after stocking. Fifteen hundred bluegill fingerlings and 100 largemouth black bass fingerlings or advanced fry are planted per acre; approximately 80 per cent of the fingerlings and 85 to 90 per cent of the advanced fry survive and reach a catchable size within a year. At this time, adult fish constitute about 80 per cent of the total weight of fish in the pond and young fish make up the remainder.

The greater percentage of survival for bass fry planted in new ponds, as compared to that for fingerlings, is explained by the relative abundance of food available for each immediately following planting. The fry, which are planted in the spring, thrive on microcrustacea and aquatic insects for some time and young bluegills are available by the time they are large enough to eat them. The fingerlings usually are planted in the fall or winter. Although they need fish for an adequate diet, they must subsist on aquatic insects, tadpoles, and possibly some *Gambusia* until the bluegills spawn the following spring.

Fish-culturists can, in effect, increase the productivity of bass hatcheries by using advanced fry instead of fingerlings for stocking new ponds. Since an average mortality of 50 to 60 per cent is experienced in the hatchery in rearing fry to the fingerling stage, the use of fry instead of fingerlings would approximately double the number of fish available for stocking.

Literature Cited

Aldrich, A. D.
1939. Results of seven years' intensive stocking of Spavinaw Lake; an impounded reservoir. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 221-227.

Brown, Merrill W.
1940. Smallmouth black bass propagation in California. Trans. Am. Fish. Soc., Vol. 69 (1939), pp. 119-124.

Davis, H. S.
1930. Some principles of bass culture. Trans. Am. Fish. Soc., Vol. 60, pp. 48-52.

Eschmeyer, R. W.
1938. Experimental management of a group of small Michigan lakes. Trans. Am. Fish. Soc., Vol. 67 (1937), pp. 120-129.

Hayford, C. O.
1926. Is the general plan of stocking with fingerlings in thickly populated sections worth while? Trans. Am. Fish. Soc., Vol. 56, pp. 181-189.

Hogan, Joe
1933. Experiments with commercial fertilizers in rearing largemouth black bass fingerlings. Trans. Am. Fish. Soc., Vol. 63, pp. 110-119.

Meehan, O. Lloyd
1939. A method for the production of largemouth bass on natural food in fertilized ponds. U. S. Bur. Fish., The Prog.-Cult., 1939, No. 47, pp. 1-19.
1942. Fish populations of five Florida lakes. Trans. Am. Fish. Soc., Vol. 71 (1941), pp. 184-194.

Swingle, H. S. and E. V. Smith
1942. Management of farm ponds. Ala. Agr. Exp. Sta., Bull. 254, 23 pp.

PHENOMENAL GROWTH RATES OF LARGEMOUTH BLACK BASS IN LOUISIANA WATERS

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ABSTRACT

Reported growth-rate studies show that largemouth black bass grow faster in the South than in the North. Southern fish make their fastest growth in length during their first year, northern fish during their second year. Fish in virgin waters grow faster than fish in more mature waters. A specimen taken from a newly dug borrow pit in Louisiana grew at the average rate of 2.5 ounces per month.

The rates of growth of various fast-growing individuals reared in captivity at the Louisiana fisheries stations as well as some northern records are given. The largest increment in a first-year Louisiana fish was 7 ounces per month during a 4-month period and in a second-year fish, 8 ounces per month during a 7-month period.

The average annual increase in length of largemouth black bass taken at random in Wisconsin waters, as given by Bennett (1937), is 3.3 inches for the first year, 4.1 inches for the second, and 3.1 inches for the third. Thus they reach the legal length of 10 inches sometime during the third summer of life. The most rapidly growing fish recorded by Bennett (1937) for Wisconsin was a specimen from Price County which weighed 4 pounds at the beginning of its fifth summer, or had an average increment of nearly a pound per year.

Bennett (1937) also showed that largemouth black bass in Louisiana grew faster during their first year (7.6 inches) than those in Wisconsin (3.3 inches) or Nebraska (3.6 inches). The greatest yearly increase in the northern fish took place during the second summer, whereas in the Louisiana fish it was during the first summer.

Eschmeyer (1939) has shown that largemouth black bass in the virgin waters of the Norris reservoir in Tennessee had an average growth of 8.2 inches during their first year and of 5 inches additional during their second year. These 2-year-old, 13-inch fish were comparable in size with 5-year-old fish from northern Wisconsin or northern Michigan, with nearly 4-year-old fish from southern Wisconsin or from Nebraska, and with 2½-year-old fish from Louisiana.

The above-mentioned studies indicate that the fish in mature waters, even in the far South, grow slowly in comparison with those in newly created waters. One largemouth black bass, taken by the writer from a 3-year-old borrow pit dug near the edge of a swamp not far from New Orleans, Louisiana, reached a length of 19.25 inches and a weight of 4 pounds, 12 ounces at the beginning of the third winter, or grew at an average rate of nearly 2.5 ounces per month of its existence.

In recently flooded ponds and abandoned drainage projects in this

general area, and in lands flooded by the lower Mississippi River during an unusual rise on that stream, especially in crevasse areas, great numbers of 1-pound largemouth black bass make their appearance towards the end of summer. Although there is no proof that these fish are young of the same year, the frequent repetition of the phenomenon, combined with other observations, lends support to that belief. It would seem, therefore, that the maximum rate of growth for wild fish of this species in the far South, in the presence of abundant and easily accessible food supplies, would average as much as 3 ounces per month during the first 5 months of life.

In captivity, the rate of growth also varies considerably, and the chief governing factor, likewise, is undoubtedly the quantity of suitable food available. The difference in the rate of growth between underfed and properly fed fish is often astounding. With inadequate food, there may be an actual loss of weight.

In 1937, before a management program was adopted at the Lacombe Station in Louisiana, the young largemouth black bass on May 8 (then not less than 2 months old) ranged in weight from 0.001 ounces to 0.011 ounces. Frequently the larger fish were seen feeding on the smaller. The largest individuals measured 1.4 inches, total length. In 1941, on April 22, a half month earlier in the year, and when the young fish were not over 2 months old, the largest individuals weighed 0.373 ounces and were 3.5 inches long. Thus they had become approximately 2½ times as long and over 30 times as heavy in the same or a shorter interval of time. The ponds in 1941 were not only fertilized but were heavily stocked with small minnows.

In early life, the multiplication in weight may be extremely rapid. On March 1, 1941, the largest young individuals, collected from the brood pond at Lacombe, averaged 0.0019 ounces each. On April 22, the largest individuals averaged 0.373 ounces, and thus had become 197 times heavier in 53 days.

Berg (1924) related an incident that occurred at the Trilake State Hatchery (Indiana) which indicates the rapid growth of largemouth black bass, even in the North, when food is plentiful. A number of fry which escaped into a goldfish hatching pond were from 4 to 8 inches long 10 weeks later. Davis and Wiebe (1930) reported that numerous fingerlings at the Fairport (Iowa) Station reached lengths of 4 to 8 inches and occasionally became longer during the 4-month season. The maximum length attained was 11.75 inches. There are other published reports of largemouth black bass attaining lengths of from 7 to 12 inches in less than 6 months.

My first records on captive fish were made at the Beechwood Station (Louisiana) in 1925, where 7- to 9-inch largemouth black bass weighing from 5.33 ounces to 12 ounces were produced in 6½ months. The length increments averaged from 1.1 to 1.4 inches per month and the weight increments from 0.8 ounces to 1.8 ounces per month. The maximum record of the year was a bass which attained a weight of 1 pound

and a length of 10.75 inches in 7 months from the egg. The average monthly length increment for this individual was 1.5 inches and the average weight increment was 2.3 ounces. J. C. Forsythe, superintendent at the same station, in the spring of 1928, reported the spawning of largemouth black bass at the age of 1 year. Ordinarily the hatchery-reared fish at this station spawned at the age of 2 years. One- and 2-year-old largemouth black bass have been known to spawn at the Bureau of Fisheries (Fish and Wildlife Service) Station at Fairport, Iowa.

At the former Concordia Station (Louisiana), by January 24, 1929, numbers of young fish had reached weights up to 1 pound, 4 ounces and lengths up to 13 inches. As the brood fish were placed in this pond, a former cotton field, on April 19, 1928, none of these fish could have been over 9 months old. The monthly weight increment for these large individuals, therefore, averaged about 2.2 ounces or over.

At both the Lacombe and Beechwood Stations during 1941, in the presence of abundant and easily available live natural foods (chiefly *Gambusia, Mollienesia, Fundulus,* suckers, and tadpoles), the fast-growing individuals attained weights up to 1 pound in approximately 5 months from the egg, and up to 2 pounds in approximately 8 months from the egg. The maximum from the egg in 11 months, the longest period any individuals were kept in the ponds, was 2 pounds, 3 ounces. The slowing down at the end may be accounted for in part by the fact that this period included the three coldest months of the year, and in part by depletion of the food supply.

In order to compare the growth of yearling bass with that of first-summer fingerlings, 5 second-summer fish and 1,000 first-summer fish, the individuals in each group of uniform size, were stocked in the 8-acre pond at Beechwood on July 18, 1941, after it has been dried out for 3 months, fertilized, and then the food supply built up for another 3 months. The pond was drawn and the fish weighed on February 14, 1942, a little less than 7 months later. The average gain for the 20 largest first-year individuals was 29.5 ounces per fish during the period. The average monthly increment was 4.3 ounces. The 2 largest individuals of this series gained 2 pounds, 2 ounces each, or had a monthly increment of approximately 5 ounces per fish. A larger increment occurred in the second-year fish, the 5 individuals of which gained an average of 2 pounds, 6 ounces each during the 7-month period, or had an average monthly increment of 5.4 ounces. A record growth was attained by an individual of this group which gained 3.5 pounds during this period, or made an average monthly gain of 8 ounces.

At the same station, the largest increment in a first-year fish occurred in a different pond. A gain of 28 ounces during a 4-month period, or of 7 ounces per month, exceeded the average for the second-year group and approached the maximum of 8 ounces per month for that group. The fish in this pond, however, were removed in the fall

while the food crop was still abundant and before any possible effect of cold weather could manifest itself.

Practical applications of the method of culture used, *viz.*, the rearing of a large food supply in separate ponds, are already producing results. G. A. C. Halff, in a pond near Leesville, Texas, caught legal-sized (10-inch) largemouth black bass in the spring of 1940, in a pond constructed in the summer of 1939 and stocked with fingerlings in the fall of 1939. Subsequently, large numbers of 10-inch fish and smaller numbers of 11-inch fish were produced from the egg in 1 year. Cason J. Calloway of Hamilton, Georgia, who employed a similar arrangement of ponds, wrote as follows on April 2, 1942: "Our information show that you can expect, under good conditions, a pound and a half per year. For instance, we caught bass weighing 5½ pounds out of Lake Florence after three years."

Literature Cited

Bennett, George W.
1937. The growth of the large mouthed black bass, *Huro salmoides* (Lacépède), in the waters of Wisconsin. Copeia, 1937, No. 2, pp. 104-118.

Berg, George
1924. Fish culture on the farm. Pub. Ind. Dept. Cons. No. 40 (revised), pp. 1-25.

Davis, H. S., and A. H. Wiebe
1930. Experiments in the culture of the black bass and other pond fish. Rept. U. S. Comm. Fish., fiscal year 1930, pp. 177-203.

Eschmeyer, R. W.
1940. Growth of fishes in Norris Lake, Tennessee. Jour. Tenn. Acad. Sci., Vol. 15, No. 3, pp. 329-341.

FURTHER STUDIES ON THE INCREASED GROWTH RATE OF THE ROCK BASS *AMBLOPLITES RUPESTRIS* (RAFINESQUE), FOLLOWING THE REDUCTION IN DENSITY OF THE POPULATION[1]

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ABSTRACT

An increased growth rate, too great to be accounted for by any normal growth fluctuation, was shown to have occurred in all age groups of rock bass, following the reduction in the population by poisoning the fish of the south basin of Booth (formerly called Standard) Lake, Michigan. Additional information was obtained in 1941 and 1942 which made it possible to analyze the change in growth in weight as well as length. Not only did the length and weight increase, but the mean coefficient of condition, *K*, also increased. Thus it appears that reduction in numbers is one solution to the problem of lakes with large populations of stunted fish.

INTRODUCTION

The effect of reducing the density of the population of rock bass in Booth Lake (formerly called Standard Lake), Charlevoix and Otsego Counties, Michigan, was reported by Beckman (1940). An increased growth rate, too great to be accounted for by any normal growth fluctuation, was shown to have occurred in all age groups of the rock bass following the reduction in the population by poisoning the fish of the south basin of Booth Lake. Additional information has been obtained on the growth of the rock bass in this lake from collections of 25 rock bass made on July 20, 1941, and of 37 fish taken on May 24-25, 1942. The 1941 collection was made by fly fishing while in 1942 four experimental gill nets (5 by 125 feet, with five sections of different mesh sizes, that varied from 1½ to 4 inches stretched measure) were used in addition to the fly rod.

CONTINUED INCREASED GROWTH RATE

The age of each fish was determined by counting the number of annuli on the scale. Measurements and growth calculations were made by the methods described in the earlier report.

At the time of the poisoning there were five legal-sized (6-inch) rock bass in the 1,233 rock bass recovered. Since the poisoning, 289 rock bass have been taken of which 20 were legal-size. Reports received from fishermen indicate that the lake is regaining some of its former popularity as a fishing lake.

[1]Contribution from the Michigan Institute for Fisheries Research.

Table 1.—Average growth increments (based on standard length in millimeters) for male rock bass from Booth Lake, according to calendar year and year of life, before and after reduction in numbers by poison

[Number of specimens in parentheses]

Computed for year of life	Calculated growth in millimeters										
	Before poisoning						After poisoning				
	1933	1934	1935	1936	1937	Average	1938	1939	1940	1941	Average
1	33(27)	32(30)	30(32)	34(17)	32(20)	32(125)	34(17)	36(25)	......	......	35(42)
2	......	20(27)	18(30)	20(32)	20(17)	19(106)	35(20)	35(17)	32(25)	......	34(62)
3	......	......	18(27)	15(30)	14(20)	16(77)	41(17)	......	35(3)	35(20)	38(40)
4	......	......	......	10(27)	12(17)	11(44)	30(20)	29(1)	......	19(3)	29(24)
5	......	......	......	......	9(5)	9(5)	28(17)	18(1)	......	......	27(18)
6	......	......	......	......	......	......	......	22(5)	11(1)	......	20(6)

Table 2.—Average growth increments (based on standard length in millimeters) for female rock bass from Booth Lake, according to calendar year and year of life, before and after reduction in numbers by poison

[Number of specimens in parentheses]

Computed for year of life	Calculated growth in millimeters											
	Before poisoning							After poisoning				
	1932	1933	1934	1935	1936	1937	Average	1938	1939	1940	1941	Average
1	31(2)	32(19)	31(41)	30(42)	33(27)	30(11)	31(141)	32(28)	34 (8)	......	......	32(36)
2	......	25(2)	21(19)	17(41)	19(42)	19(19)	19(123)	37(12)	30(28)	27(8)	......	31(48)
3	......	......	16(2)	18(19)	16(41)	16(32)	16(94)	29(19)	19(1)	37(22)	27(7)	32(49)
4	......	......	......	6(2)	8(19)	12(24)	10(45)	27(32)	......	30(1)	17(10)	25(43)
5	......	......	......	......	6(2)	......	6(2)	24(24)	19(1)	......	13(1)	23(26)
6	......	......	......	......	......	......	......	......	24(1)	......	......	24(1)

The average calculated annual increments of length for each of several year classes of males and females according to year of life, and average calculated increments for all year classes combined before and after the poisoning, are presented in Tables 1 and 2. A decided increase in growth occurred after the reduction in numbers, and the increased growth rate has been maintained rather well for the 4 years following the poisoning. The males have a slight advantage over the females in growth, and this advantage has been somewhat more evident following the poisoning. The grand average calculated lengths, based upon the successive addition of the weighted average growth increments, are shown in Figure 1 and Table 3. There was very little difference between the lengths at the end of the first year of life before and after the reduction in the density of the population. This may be due to the nature of the feeding habits of the young of the year and older age groups. The young of the year are mainly plankton feeders, and the plankton in the lake probably was sufficiently abundant to provide a normal food supply to all these fish. However, the food supply for the older fish probably was not sufficient with the result that stunting was prevalent before the poisoning. Following the poisoning the food available was adequate to supply the remaining fish enough food to permit improved growth. In fact, the growth after 1937 was found to be better than average when compared with the tentative state average (unpublished data).

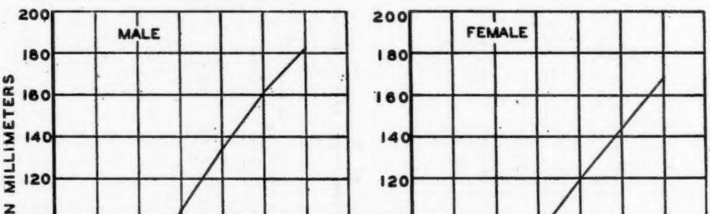

Figure 1.—Growth of rock bass in Booth Lake, before (broken lines) and after (solid lines) reduction in the density of the population. Growth curves (upper curves) based upon successive addition of the grand average calculated increments in length (lower curves).

Table 3.—Grand average calculated lengths based on the successive addition of average calculated increments before and after poisoning

Year of life	Before poisoning		After poisoning	
	Male	Female	Male	Female
1	32	31	35	32
2	51	50	69	63
3	67	66	107	95
4	78	76	136	120
5	87	82	163	143
6	....	....	183	167

Growth in Weight

No attempt was made to analyze the growth in weight in the earlier report. The length-weight relationship has been determined for the materials collected after the reduction in numbers. Equations were calculated originally for the sexes separately, but the differences between them were so small that a combination of the data was considered justifiable. The equation for the combined data is:

$$W = 3.597 \times 10^{-5} L^{3.025},$$

where W = weight in grams,
and L = standard length in millimeters.

In logarithmic form the equation may be stated:

$$\log W = -4.4440438 + 3.025 \log L.$$

From this equation the weights corresponding to the lengths at the end of each year of life for growth after the reduction in population density were calculated and are given in Table 4 and Figure 2.

No individual weights were taken at the time of the poisoning. A collection of 13 fish (range of standard length—79 to 99 millimeters) was made in August, 1937, just a month prior to the poisoning. The average coefficient of condition, K, for these fish, which were weighed individually, was determined as 3.07—a value much lower than that of 4.10 for rock bass after the poisoning. The difference in condition in the two periods is evident when a comparison is made of the estimated weights for the rock bass of the same length before and after poisoning. A 50-millimeter fish, before the poisoning, would have weighed 4 grams, while after the poisoning fish of the same length would have weighed 5 grams, and the corresponding weights for a fish 75 millimeters long are 13 grams and 17 grams respectively. Because of the evidence for a pronounced improvement in the condition following the reduction in density of the population, it was considered advisable to base estimates of the growth in weight before poisoning on the coefficient of condition of fish taken at that time (though based on relatively few individuals) rather than on the length-weight equation determined from fish taken after the poisoning.

Of course, the use of an average coefficient of condition for the computation of unknown weights from known lengths is valid only if the length-weight relationship conforms rather closely to the "cube law,"

Table 4.—Calculated weight for calculated lengths at end of each year of life

	Males					Females			
	Before poisoning		After poisoning			Before poisoning		After poisoning	
Year of life	Calculated length (millimeters)	Calculated weight (grams)	Calculated length (millimeters)	Calculated weight (grams)	Year of life	Calculated length (millimeters)	Calculated weight (grams)	Calculated length (millimeters)	Calculated weight (grams)
1	32	1	35	2	1	31	1	32	1
2	51	4	69	13	2	50	4	63	10
3	67	9	107	50	3	66	9	95	35
4	78	15	136	103	4	76	14	120	70
5	87	20	163	177	5	82	17	143	119
6	....	....	183	251	6	....	....	167	191

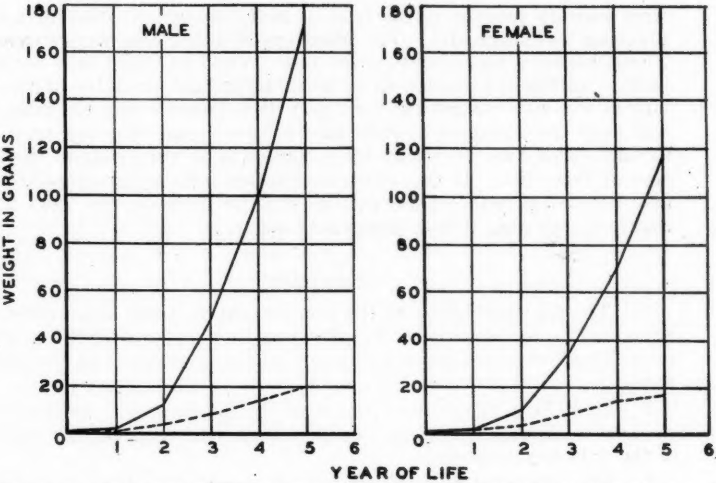

Figure 2.—Calculated weight of rock bass from Booth Lake at end of each year of life before (broken lines) and after (solid lines) reduction in numbers.

that is, if the exponent in the length-weight equation deviates only slightly from the value 3. There is considerable evidence that in general the weight of the rock bass tends to increase approximately as the cube of the length. The value of the exponent for Booth Lake fish (after poisoning) was given above as 3.025. In the length-weight equation derived by Hile (1941) for the Nebish Lake (Wisconsin) rock bass, the exponent was 3.003. Finally, the value in the equation for combined samples of rock bass from different localities throughout the state of Michigan (Beckman, MS) was 2.969. These values are all sufficiently close to 3 to suggest that no great systematic error was involved in the use of the mean K for the estimation of the growth in weight before the population density was reduced.

Thus the reduction in the density of the rock bass population was followed by increases in the rate of growth in length and weight, and in the coefficient of condition.

One additional factor has now entered into the problem. In 1937, after the poisoning, a planting of 25 adult smallmouth black bass (*Micropterus d. dolomieu*) was made, and in 1938 fingerlings were planted as follows: 200 largemouth black bass (*Huro salmoides*); 5,000 bluegills (*Lepomis m. macrochirus*); and 1,500 perch (*Perca flavescens*). None of the bluegills have been recovered to date. As perch[2]

[2]An insufficient number of perch has been taken since the poisoning to determine whether or not any change in growth rate has occurred in this species.

were already present in the lake, it is not known whether or not the planting was successful. The plantings of black bass were successful. These fish have reproduced in the lake. The black bass may now have become sufficiently numerous to be an important predator of the rock bass as well as a competitor for food. It is possible that the black bass will keep the numbers of rock bass reduced, and that the rock bass, through predation on young black bass, will in turn control the numbers of those fish. If this situation obtains both species should maintain normal growth. Observations will be made on the lake in the future to ascertain what changes may occur.

Summary

1. The fish population of the south basin of Booth Lake (formerly Standard Lake), Michigan, was destroyed by poison in 1937 to determine the effect of reduction in density of the population on the growth rate.

2. In 1940, a report was presented on the increased length of the rock bass. Additional collections have been made and further analysis of the data are presented.

3. The increased rate of growth in length has been maintained rather well.

4. Growth in weight also increased sharply following the reduction in population density. Furthermore, the mean coefficient of condition, *K*, was much greater (4.10) after than before the poisoning (3.07).

5. The reduction in the density of the population therefore appears to be one solution to the problem of improving fishing in the lakes overrun with stunted fish.

Literature Cited

Beckman, William C.
1941. Increased growth rate of rock bass, *Ambloplites rupestris* (Rafinesque), following reduction in the density of the population. Trans. Am. Fish. Soc., 1940, Vol. 70, pp. 143-148.

Hile, Ralph
1941. Age and growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in Nebish Lake, Wisconsin. Trans., Wis. Acad. Sci., Arts, Let., Vol. 33, pp. 189-337.

TAXONOMY AND HABITS OF THE CHARRS, *SALVELINUS MALMA* AND *SALVELINUS ALPINUS*, OF THE KARLUK DRAINAGE SYSTEM

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ABSTRACT

In the course of a study of the importance of charrs as predators on the red salmon of the Karluk watershed on Kodiak Island, Alaska, during the summers of 1939 to 1941, it became apparent that two distinct species of charrs were present. Results of tagging experiments, of stomach examinations of thousands of charrs, and of the analysis of comprehensive morphometric and meristic data made it easy to separate the dolly varden charrs from the red lake or alpine charrs at Karluk. These species have often been confused with each other, and may show intergradation in other parts of the world. At Karluk, however, the dolly varden charr, *Salvelinus malma* (Walbaum), is typically anadromous, spawns in streams, and has fewer than 20 gill rakers and fewer than 35 pyloric caeca. The red lake or alpine charr, *Salvelinus alpinus* (Linnaeus), of the same region is not anadromous, spawns in the lake, and has more than 20 gill rakers and more than 35 pyloric caeca.

INTRODUCTION

The large runs of red salmon to the Karluk River in the 1880's were responsible for the development of an intensive fishery which has since maintained considerable importance, although the abundance of the red salmon has suffered a marked decline through the years. In 1921 the Karluk red salmon became the object of a federal investigation which has been continued to date. Mr. J. T. Barnaby, in charge of the investigation from 1930 to 1938, became interested in the predatory relationship existing between charrs and red salmon and initiated a series of observations on the Karluk charrs, including tagging experiments and the analysis of stomach contents. Since 1938 the authors have collected many additional data on these and other phases of the problem. The purpose of the present paper is to present the information that has been obtained concerning the taxonomic relationships of the two Karluk charrs, *Salvelinus malma* and *Salvelinus alpinus*.

The Karluk watershed is located in the western part of Kodiak Island, Alaska, at approximately 154° W. Long. and between 57° and 58° N. Lat. There are three lakes in the drainage system. The two smaller ones, Thumb Lake and O'Malley Lake, drain into the third, Karluk Lake, which is by far the largest of the group. Karluk Lake, which lies about 350 feet above sea level, is 12 miles long and has an average width of slightly more than one mile. The maximum depth is 413 feet, and the lake is characterized by a very limited littoral area. The lake normally freezes over during the winter. In summer the

maximum surface temperature rarely exceeds 15° C. and usually varies between 10° and 12°C. The physical features of Karluk Lake were fully described by Juday, Rich, Kemmerer, and Mann (1932). The lake is drained by Karluk River which is approximately 30 miles long and enters Shelikof Strait near Karluk Head.

Taxonomy of the Charrs

The terms salmon, trout, and charr were first used in England. Today in America we commonly speak of salmon and trout, but the word charr has never come into common usage. The authors believe that its use should be encouraged. Regarding the spelling and origin of the term, Webster's *New International Dictionary* says: "*Char,* n; pl. char(collective) or chars. Also *charr* (Gaelic *ceara* lit., red, blood-colored; French cear, blood, from its red belly)." Charr is a distinctive name for the genus *Salvelinus,* and if brought into general usage it would afford a measure of relief to the much over-burdened term of "trout."

Although charrs are little known by that name in this hemisphere, they are common, and one of them, usually termed the eastern brook or speckled "trout," *Salvelinus fontinalis* (Mitchill), is among the best-known sport fishes in America. Other charrs, less widely distributed than the eastern brook trout, are also highly prized by fishermen. As game fish the charrs enjoy a varying yet usually excellent reputation, depending somewhat upon the type of habitat in which they are found. The dolly varden charr, *Salvelinus malma* (Walbaum), which is widely distributed about the rim of the North Pacific Ocean, is highly regarded as a game fish by some, although by others it is held in disrepute, probably as a result of its habits as a scavenger.

According to Jordan and Evermann (1896) charrs were placed in the genus *Salmo* by Linnaeus (1758) in his *Systema Naturae.* Later Nilsson (1832) used the term *Salvelini* as a group name for the charrs, and in 1836 Richardson initiated the use of *Salvelinus* as a full generic term and characterized the genus. For many years *Salmo* was retained by some authors as inclusive of the charrs. Although gradual acceptance of the new genus has occurred, its adoption has been somewhat more rapid in America than in Europe. This relatively simple history of the establishment of the genus is in marked contrast to the controversy that has developed in regard to the interrelationships of the charrs themselves.

The first species of charr to be described by Linnaeus (1758) is the form now known as *Salvelinus alpinus.* In subsequent years a few charrs quite unlike the genotype have been found, but they have been considerably outnumbered by the discoveries, throughout the northern hemisphere, of forms closely related to the original *S. alpinus.* Many well-known taxonomists have either affirmed or denied that these forms are specifically distinct. A few of those who favor the division of the alpinoid charrs into numerous species include: Günther (1866), Jor-

dan and Evermann (1905), Regan (1911, 1914), Kendall (1914), Jordan, Evermann and Clark (1930), and Pratt (1935). Recent proponents of this concept number the distinct species of American charrs at eleven and list one American subspecies, *Salvelinus malma spectabilis,* (Jordan, Evermann and Clark, 1930).

A partial list of those who have recognized or favored the recognition of various subspecies within the *S. alpinus* series includes: Yarrell (1836), Seeley (1886), Jordan and Evermann (1896 although their opinion was later changed), Bajkov (1927), Surovov (1929), Berg (1932), Dymond (1932), Popov (1933), and Schrenkeisen (1938). Opinion among this group of workers has usually favored the recognition of three or four polymorphic species as constituting the genus *Salvelinus.* Bajkov, Surovov, Dymond, and Popov have gone further than some and have suggested that *S. malma* is a subspecies of *S. alpinus.*

After examining large numbers of dolly varden charrs, as well as equally large numbers of an alpinoid representative, both of which occur in Karluk Lake, Alaska, the present authors feel that the specific differences between the two forms cannot be questioned; supporting data will be given in the later sections. The name *Salvelinus malma* (Walbaum) should, therefore, be retained as the name of the dolly varden or Pacific charr. Because of the great variability within the various species of charrs, and because adequate samples of dolly varden charrs from the southern part of their range are not at present available to us, the authors offer no comment on the validity of the subspecies *S. malma spectabilis.* The name *Salvelinus alpinus* (Linnaeus) is adopted provisionally for the Karluk representative of the alpinoid series of charrs. The assignment of this fish to a new or already known subspecies must await a thorough study of the relationships of all the members within the series. The junior author has begun the collection of data for such a study.

Collection and Presentation of Data

The specimens of *S. malma* and *S. alpinus* used in the preparation of this report were collected from Karluk Lake and its affluents from June to September inclusive in 1939, 1940, and 1941. Most of the specimens were measured and studied as fresh material in the field, although some of the data were taken from preserved specimens. The smaller fish in particular were difficult to measure unless first hardened in formalin. Upon final compilation of the data accumulated in the field it was found desirable to augment with measurements from preserved specimens the inadequate data in a few of the size groups. As nearly as possible in each size group equal numbers of males and females were selected for measurement and examination. The morphometric data derived from these charrs are presented in Table 1 and the meristic data in Table 2.

Table 1.—Means and standard errors of the means of body measurements of (m) *body*

Character		18-50			51-100			101-150		
		N	Mean	S.E.	N	Mean	S.E.	N	Mean	S.E.
Total length	m	15	46.7	3.02	21	102.1	3.08	13	155.4	4.74
	a	10	56.7	2.28	12	99.2	5.31	13	154.6	5.13
Standard length	m	15	42.0	2.87	21	95.7	3.47	13	147.9	4.02
	a	10	51.2	2.09	16	93.8	4.20	13	152.0	4.60
Standard body length (StBL)	m	15	33.5	2.27	21	79.1	3.01	13	123.5	3.38
	a	10	41.0	1.77	16	76.5	3.33	13	124.3	3.85
Occipital head length (HLoc)	m	15	8.5	0.59	21	16.6	0.53	13	24.4	0.75
	a	10	10.2	0.41	16	17.3	0.72	13	27.6	0.84
Opercular head length (HLop)	m	8	10.3	0.57	12	21.2	0.76	10	33.9	1.27
	a	10	12.9	0.58	14	22.3	0.89	7	38.5	0.9
Interorbital width	m	9	3.5	0.30	12	6.8	0.30	13	10.0	0.3
	a	10	3.5	0.13	12	5.9	0.39	13	10.2	0.3
Diameter of eye (Eye)	m	10	2.6	0.15	10	4.5	0.21	11	5.9	0.1
	a	10	4.1	0.15	12	5.9	0.20	11	7.2	0.1
Head depth through center of eye	m	9	6.7	0.51	11	11.1	0.52	13	16.1	0.4
	a	10	6.6	0.32	13	11.7	0.60	10	17.0	0.7
Body depth at pectoral fin	m	10	9.2	0.80	12	18.1	0.76	13	26.0	0.8
	a	10	9.2	0.44	12	16.3	0.96	13	26.1	0.8
Body depth at ventral fin	m	10	8.5	0.84	12	18.6	0.87	13	27.5	0.9
	a	10	8.1	0.39	12	15.5	1.07	13	26.1	0.8
Least peduncle depth (Pd)	m	10	4.6	0.39	12	8.7	0.37	13	12.3	0.4
	a	10	4.2	0.17	12	7.3	0.36	13	11.5	0.3
Ventral fin length	m	10	6.3	0.66	12	12.0	0.42	13	17.0	0.3
	a	10	6.9	0.32	12	12.0	0.57	13	19.0	0.5
Pectoral fin length	m	10	8.5	0.78	12	15.8	0.55	13	22.1	0.5
	a	10	9.3	0.46	12	16.4	0.91	13	25.7	0.6
Dorsal fin length	m	10	6.6	0.66	12	12.8	0.55	13	17.2	0.3
	a	10	7.9	0.54	12	13.8	0.49	13	18.5	0.5
Dorsal fin base	m	10	6.1	0.56	12	12.0	0.59	13	17.9	0.6
	a	10	6.1	0.29	12	10.4	0.49	13	16.5	0.6
Dorsal fin, standard position	m	9	11.5	1.23	12	27.5	1.72	13	41.1	0.9
	a	10	14.1	0.61	12	26.7	1.55	13	42.3	1.2

Salvelinus malma *and (a)* Salvelinus alpinus. *Size groups are based on standard length.*

Size g oups in millimeters														
151-200			201-250			251-300			301-350			351-400		
N	Mean	S.E.	N	Mean	S.E.	N	Mean	S.E.	N	Mean	S.E.	N	Mean	S.E.
16	219.4	5.03	13	283.8	5.49	19	353.6	4.80	20	419.0	5.75	14	483.3	5.96
19	218.9	4.38	17	284.7	4.03	17	356.5	5.07	20	426.0	5.10	13	491.2	5.99
16	209.4	4.50	13	267.0	4.69	19	331.6	3.76	20	391.0	4.99	14	446.9	5.18
19	209.0	3.72	17	270.7	4.24	17	335.6	4.66	20	396.8	4.36	13	457.7	5.05
16	176.4	3.93	13	224.4	4.24	19	279.3	3.05	20	326.0	3.80	14	371.1	3.05
19	172.7	3.14	17	224.6	3.47	17	276.7	3.98	20	324.2	3.42	13	375.0	3.55
16	32.9	0.76	13	42.6	0.75	19	52.4	0.94	20	65.0	1.85	14	75.9	2.73
19	36.2	0.74	17	46.1	1.01	17	58.9	1.14	20	72.6	1.30	13	82.6	1.75
13	45.2	1.65	11	51.3	2.21	8	68.0	2.03	4	86.8	4.43	9	101.5	3.93
10	48.9	1.33	5	62.9	3.23	2	75.5	3.50	7	98.5	2.21	7	113.1	4.47
16	14.8	0.37	13	1[illegible].2	0.38	19	25.0	0.48	20	30.4	0.63	13	36.2	0.78
19	14.9	0.37	17	19.9	0.38	17	26.2	0.45	20	32.9	0.54	13	39.2	1.17
10	7.2	0.25	9	8.0	0.24	18	9.2	0.19	20	10.5	0.15	13	11.2	0.13
15	9.1	0.21	15	10.7	0.32	16	11.2	0.14	19	12.6	0.18	12	13.4	0.45
15	22.2	0.53	12	28.2	0.84	12	34.8	0.62	10	43.9	1.33	5	50.4	1.08
10	23.3	0.83	9	32.3	0.67	10	42.4	1.24	12	51.1	1.44	4	59.7	3.33
16	35.9	0.89	13	45.5	1.33	19	58.3	0.87	20	71.4	1.40	14	78.9	1.71
19	35.6	0.75	17	47.5	1.00	17	63.6	1.47	20	78.8	1.60	13	89.5	1.66
16	40.1	1.10	13	51.8	1.70	19	65.4	1.36	20	81.4	1.74	14	88.9	2.22
19	36.7	0.80	17	49.1	1.03	17	63.9	1.49	20	77.5	2.23	13	85.8	2.11
16	17.6	0.44	13	21.9	0.57	19	27.5	0.54	20	33.8	0.65	14	38.5	0.77
19	15.4	0.31	17	19.8	0.37	17	25.9	0.51	20	30.8	.48	13	33.8	0.63
16	23.5	0.67	13	31.2	0.80	19	39.1	0.92	20	49.8	1.23	14	61.0	1.92
19	25.8	0.62	17	33.8	0.92	17	45.5	1.23	20	62.0	1.77	13	69.8	1.23
16	29.5	0.71	13	38.1	0.80	19	48.8	0.92	20	60.4	1.23	14	74.3	1.87
19	34.7	0.81	17	44.7	1.26	17	61.1	1.64	20	82.6	2.15	13	91.5	2.09
16	23.1	0.56	13	29.8	0.95	19	37.8	0.78	20	47.7	0.88	14	55.7	1.66
18	25.1	0.52	17	32.2	0.78	17	40.4	0.94	20	50.7	1.26	13	58.2	1.67
16	25.6	0.67	13	31.9	0.75	19	39.1	0.85	20	47.8	1.05	14	54.6	0.91
19	23.1	0.47	17	28.7	0.57	17	37.4	0.95	20	45.4	0.83	13	50.1	1.37
16	58.0	1.46	13	73.5	2.27	19	91.5	1.28	20	107.4	1.49	14	122.1	1.27
18	58.3	1.33	17	76.0	1.44	17	97.5	2.04	20	115.2	1.61	13	133.6	1.77

For the presentation of the morphometric data of Table 1 the fish were grouped by 5-centimeter intervals of standard body length (standard length minus occipital head length). In each size group the number of specimens measured, the mean value and the standard error of the mean are given in millimeters. It is believed by the authors that this manner of presentation is distinctly advantageous, since much work remains unfinished concerning the relationship of the species within the genus *Salvelinus,* and the data of Table 1 should prove to be of more value to future workers than would the presentation of only the more commonly used ratios. Since the characters presented here vary with size, the relationship between standard body length, for example, and any character measurement will have to be more thoroughly examined before these data can be combined into body measurement ratios. The validity or usefulness of such ratios will not be considered at this time. Although other measurements were made, only those most suitable to our present purpose are presented in Table 1.

The meristic data for both species involved in this discussion are presented in Table 2. In counting the gill rakers, the raker in the angle was counted with those on the upper arch. In the up-turned posterior end of the vertebral column the fused vertebrae were counted as one. The pyloric caeca were hardened in formalin before counting. Because scale counts show such variability and are so difficult to make in both *S. malma* and *S. alpinus,* the utility of these counts is considered to be much less than that of the gill-raker or pyloric-caeca counts.

Six of the measurements used in Table 1 are projected lengths; that is, the fish were laid on a measuring board and points mentioned below

Table 2.—Means and standard errors of meristic characters of Salvelinus malma *and* Salvelinus alpinus

Character	*S. malma*			*S. alpinus*		
	N	Mean	S.E.	N	Mean	S.E.
Gill Rakers:						
Upper arch	62	7.8	0.13	70	9.8	0.08
Lower arch	62	10.3	0.11	70	13.5	0.10
Total	62	18.1	0.20	71	23.4	0.13
Vertebrae:						
Abdominal	37	36.6	0.16	53	39.4	0.15
Caudal	37	25.7	0.19	53	25.2	0.13
Total	37	62.3	0.17	53	64.7	0.17
Pyloric caeca	84	28.8	0.43	60	45.6	1.02
Scales:						
Along lateral line	13	243.0	3.05	15	217.3	3.20
Above lateral line	15	42.0	0.72	15	34.0	0.95
Below lateral line	15	42.1	0.72	15	35.7	0.95
Dorsal fin rays	64	10.5	0.09	57	10.0	0.07
Anal fin rays	63	9.0	0.07	57	9.0	0.06
Branchiostegals	57	11.3	0.30	37	11.3	0.38

were measured off on a steel tape fastened to the board in such a manner that its zero mark was even with the face of a small block of wood against which the snout of the fish was pressed. These are as follows:

Character	*Definition*
Total length	Tip of snout to posterior end of middle rays of caudal fin.
Standard length	Tip of snout to end of scales on tail.
Standard body length	Occipital point to end of scales on tail.
Occipital head length	Tip of snout to occipital point.
Opercular head length	Tip of snout to posterior margin of operculum.
Dorsal fin position	Occipital point to anterior insertion of the fin.

All other measurements were made with the dividers. The eye diameter was recorded as the average of the perpendicular and horizontal diameters. Special mention should be made of the point designated in this paper by the term "occipital point," which is the point of cleavage of the operculum from the dorsal region of the head. This point proved to be of particular value as a fixed external position by which the head and trunk may be conveniently separated. Use of the occipital position was suggested to us by Dr. F. A. Davidson.

Dolly Varden Charr, *Salvelinus malma* (Walbaum)

In addition to the common name of "dolly varden," *Salvelinus malma* (Walbaum) is occasionally referred to in America as the Pacific charr, western charr, western brook trout, Alaskan bull trout, sea trout, or salmon trout, and in Asia as the malma trout or goletz. The species ranges from northern California northward to both the American and Asiatic shores of the Arctic Ocean, and southward along the Asiatic coast to Japan and Korea. The dolly varden charr is typically anadromous although populations landlocked by impassible falls are of common occurrence, and in the southernmost portions of its range it does not migrate to and from the ocean even in streams unobstructed by natural or artificial falls and dams.

The total length of the adult dolly varden charrs most frequently encountered in the Karluk watershed was between 35 and 45 centimeters. Specimens over 60 centimeters long were rare. The longest Karluk specimen on record measured 72 centimeters. This fish was captured in fresh water while on its way to the sea. The heaviest fish encountered by us was caught in salt water near the mouth of the Karluk River and weighed 5¼ pounds although it was but 62 centimeters long.

The coloration of the species varies widely from season to season and according to sex and the degree of maturity. During the spring downstream migration, when the dolly varden charrs are thin and in rather poor condition, they are pale pea-green above, with many lighter, round dots, usually smaller than the pupil, on both back and sides, and are white beneath. The lower fins are white or pale gray. As observed at the mouth of the Karluk River upon their return from the

sea in late summer, these dolly vardens are plump, and much darker green above with the lighter markings showing more sharply. Maturing fish often show pale red dots on the sides, and the lower fins are relatively dark, or in some specimens have acquired a reddish tinge. The bellies of some change from white to orange. Fully mature specimens taken in the fall from affluents of Karluk Lake are dark green or blackish above, sharply scrawled or speckled with lighter markings, and with the sides showing many red dots smaller than the pupil; the color of the bellies ranges from yellow to red, and all the lower fins become red-tipped. The ventral and anal fins are margined anteriorly with white, but the pectoral and the lower rays of the caudal very seldom if ever exhibit this condition.

Perhaps the most conspicuous feature in the life history of the dolly varden is its habit of migrating regularly to and from salt water. At Karluk the seaward movement occurs in the latter part of May and in early June. Although the majority of the population participates in the migration, it is known that some dolly vardens remain behind, because adult representatives of the species are present in the Karluk system during late June and early July, at a period when no charrs are moving either up or down the river. The return migration from salt water to fresh water takes place from mid-July until September after an average residence in the ocean of approximately 60 days, as determined by tagging experiments (DeLacy, 1941). It is not known yet whether some of the charrs stay in the ocean for a year or more before returning to fresh water.

During their residence in fresh water adult dolly varden charrs frequent both the lakes and the streams of the Karluk watershed, concentrating in one habitat or the other at various seasons of the year. In April and May, 1940, for instance, relatively few adult dolly vardens were encountered in the tributaries of Karluk Lake, although large schools were present in both Thumb and Karluk Lakes. The reverse of this condition prevails in late summer and fall. The larger streams of the Karluk drainage system have been found to be the principal habitat of juvenile dolly vardens whose total lengths range from 2 to 15 centimeters. Specimens in this size range have seldom been encountered in Karluk Lake.

The spawning of the dolly varden has not been observed at Karluk. However, from the examinations of gonads and from knowledge of the habits of the species in other localities it seems likely that spawning begins in the late fall and continues on into the winter months. The dolly varden is known as a stream spawner, and that it exhibits this habit at Karluk is indicated by the presence of newly-hatched fry in the streams in the early summer, as well as by the obvious concentration of maturing adults in the larger streams in early fall. Unpublished data on the chronology of sexual development show that not all individuals spawn each year.

The feeding habits of the dolly varden charr in fresh water vary

markedly from season to season. In the spring, prior to the time of their seaward migration, dolly vardens feed mainly on larval and adult insects, snails, and leeches. Stomach examinations made from fish caught in Karluk River during both the upstream and the downstream migration showed fewer than 20 per cent of the fish had been recently feeding. In the fall, when once again in fresh water, dolly vardens feed most commonly on salmon eggs, with insects next in importance in their diet. Forty per cent of the stomachs examined in the fall were empty. The position of the dolly varden as a salmon predator is beyond the scope of the present paper but will be dealt with in a subsequent publication. It may be said here, however, that as judged by studies made at Karluk, the seriousness of the dolly varden as a salmon predator has often been overstated.

A brief characterization of *Salvelinus malma* based on the Karluk specimens and arranged to facilitate the recognition of some of the differences between *S. malma* and *S. alpinus* will be found in the last section of this paper.

Red Lake or Alpine Charr, *Salvelinus alpinus* (Linnaeus)

Of the many common names that have been given to the various alpinoid charrs, the name "red lake charr" seems best suited to the Karluk representative of the series. Although "dolly varden" has been and still is often used to include both *S. malma* and *S. alpinus,* its use should be strictly limited to the former species. Some other common names for *S. alpinus* are Arctic charr, European charr, red trout, Canadian red-bellied trout, and lake trout.

The alpinoid charrs have a circumpolar distribution. The species characteristically inhabits cold water; in the southernmost part of its range it is known only as a landlocked form occurring in high lakes. Some of the most northern representatives of the series are said to be anadromous, but the southern limit at which migratory populations occur is much farther north than the corresponding limit for the dolly varden. Observations, together with the results of tagging experiments (DeLacy, 1941) have shown that the Karluk alpinoid is nonmigratory. Only on rare occasions is it encountered in the river below Karluk Lake, and specimens are seen in salt water still less frequently.

The average total length of red lake charrs, as represented by beach-seine catches, usually ranges between 35 and 45 centimeters. Of hundreds of specimens measured since 1937, the largest was 55 centimeters long and weighed 3 pounds, 3 ounces.

There is some seasonal variation in the color of the red lake charr, although this variation is less than was noted in *S. malma.* The Karluk alpinoid is commonly olive-tan above with each imbedded scale often showing a golden-yellow glint. Very few of the older fish show any spots on the back, although in younger ones the back is sometimes marked with scattered, round, light dots. The sides blend from olive-

tan dorsally to golden-yellow or orange ventrally and usually show a bright pink or red wash with irregularly placed round and bright rosy-pink dots, many of which are at least as large as the pupil. The belly is seldom white in adult fish, but is usually yellow or orange or even deep red. The lower fins are brightly colored and ornately elongate in mature fish, with the first ray of each being white. Pectorals and ventrals are blue-gray proximally and bright vermillion distally in mature fish. The caudal fin in adults is also bordered distally with red. In immature fish the lower fins are dull and not margined with white, nor are they elongate.

Salvelinus alpinus, as known at Karluk, is essentially a lake inhabitant throughout its life. Half-grown specimens and a very few full-grown ones are found from time to time a short distance up some of the lake's tributaries, yet the number of fish encountered in the streams is an insignificant proportion of the total population. Within the lake itself, these lake charrs are widely dispersed. Good catches may be made by gill net in water as deep as 200 feet, and one lake charr 20 centimeters long was taken in a net at a depth of 300 feet. The smallest lake charr (43 millimeters) yet seen from the Karluk system was taken from the lake. Careful examination of the tributaries of the lake has left little doubt that the majority of the lake charrs spend their entire lives in the lake itself.

Although a female with mature pale yellow ova was taken from Karluk Lake in the fall of 1939, the actual spawning of the lake charr has not been observed by us as yet. Spawning undoubtedly occurs during the late fall or early winter and probably takes place in the lake if the habits of other charrs in the alpinoid series are possessed by the Karluk representative. The total absence of young lake charrs in the lake's tributaries during the early summer gives a further indication that spawning does not take place in the streams.

Until late June, insects are the most common food eaten by these charrs. As soon as the red salmon begin to spawn in the tributaries of the lake in late June or early July, schools of lake charr may be found congregated about the mouth of each stream. At this time of the year they eat not only the salmon eggs that drift downstream into the lake, but also other food material dislodged in the streams by the spawning salmon. Later in the season as the disintegrating carcasses of the dead, spawned-out salmon accumulate in the lake, fragments of this flesh become the most common item in the diet of the lake charr. Fish caught in shallow portions of the lake feed quite heavily on sticklebacks during certain seasons. Cottids, salmon fingerlings, and young charrs are found occasionally in their stomachs. During September, insect material again resumes its earlier position as an important source of food.

A Comparison of *Salvelinus malma* and *Salvelinus alpinus*

A brief characterization of *S. malma* and *S. alpinus* based upon the

morphometric and meristic data collected from Karluk specimens, and arranged to facilitate the recognition of some of the differences between the two species, is presented in this section. The morphometric ratios presented in Table 3 were derived from Table 1 to bring out some of the more marked differences between the species and to give some indication of how such ratios vary with the size of specimens examined.

Table 3.—Body ratios of S. malma *(m) and* S. alpinus *(a) by size groups*

Upper limit of size group in centimeters (StBL)	5	10	15	20	25	30	35	40
StBL/HLop ....(m)	3.2	3.7	3.6	3.9	4.4	4.1	3.8	3.7
(a)	3.2	3.4	3.2	3.5	3.6	3.7	3.3	3.3
StBL/HLoc ....(m)	3.9	4.8	5.1	5.4	5.3	5.3	5.0	4.9
(a)	4.0	4.4	4.5	4.8	4.9	4.7	4.5	4.5
HLop/Pd ....(m)	2.2	2.4	2.8	2.6	2.3	2.5	2.6	2.6
(a)	3.1	3.1	3.3	3.2	3.2	2.9	3.2	3.3
HLoc/Pd ....(m)	1.8	1.9	2.0	1.9	1.9	1.9	1.9	2.0
(a)	2.4	2.4	2.4	2.4	2.3	2.3	2.4	2.4
HLoc/Eye ....(m)	3.3	3.7	4.1	4.6	5.3	5.7	6.2	6.8
(a)	2.5	2.9	3.8	4.0	4.3	5.3	5.8	6.2
Pd/Eye ....(m)	1.8	1.9	2.1	2.4	2.7	3.0	3.2	3.4
(a)	1.0	1.2	1.6	1.7	1.9	2.3	2.4	2.5

As suggested in a previous section of this paper, it is not considered necessary at this time to discuss the usefulness of body ratios in order to fulfill the purpose of this paper, which is to present the differences found in the two Karluk charrs. However, due to the axial gradient in the development of the body of fishes, *i.e.*, the greatest growth taking place nearest the head, the ratio of any character over the standard length or standard body length is not constant because of the variability of both the head and trunk with size, age, and degree of maturity. It is therefore preferable to indicate some morphometric differences between these two species which can be readily observed from the data in Table 1. These characters may be summarized as follows: (Characters are for fish in same size groups.)

Character	*S. malma*	*S. alpinus*
(a) All head measurements including the eye	Smaller	Larger
(b) Body depths of mature fish (over 25cm. StBL)	Deeper at ventral fin	Deeper at pectoral fin
(c) Body depths of younger fish	Ventral fin depth greater than at pectoral fin	Ventral and pectoral fin depths about equal
(d) Caudal peduncle depth..	Larger	Smaller
(e) Dorsal fin length and base	Base about equal to the length	Length greater than the base
(f) Lateral fins	Shorter •	Longer

Character	*S. malma*		*S. alpinus*	
Summary of meristic data from Table 2:				
(a) Number of gill rakers....				
Upper arch	predominantly	8	predominantly	10
	range	5-11	range	7-12
Lower arch	predominantly	10	predominantly	13
	range	8-12	range	12-15
Total	predominantly	18	predominantly	23
	range	15-22	range	21-26
(b) Number of vertebrae:				
Abdominal	predominantly	37	predominantly	39
	range	34-38	range	37-41
Caudal	predominantly	25	predominantly	25
	range	24-29	range	23-27
Total	predominantly	62	predominantly	65
	range	60-64	range	63-67
(c) Number of pyloric caeca	predominantly	30	predominantly	45
	range	21-39	range	30-64
(d) Number of oblique scale rows intersecting the lateral line	predominantly	240	predominantly	220
	range	218-254	range	195-236

Other features observed but not presented in either Table 1, 2 or 3:

Character	*S. malma*	*S. alpinus*
(a) Snout development	Elongate in mature males with large hook and groove	No such elongation and very slight hook if present
(b) General basic color	Green or black	Brown or red
(c) Red dots on sides	Numerous (50+) and small (less than diam. of pupil)	Less numerous (50—) and large (many about diam. of pupil)
(d) Habitat	Anadromous; stream spawners	Not anadromous; lake spawners
(e) Color of eggs	Orange	Pale yellow
(f) Swim bladder	Transparent, thin-walled	Opaque, pinkish and tough
(g) Usual physical condition encountered	Sparsely parasitized; dark maroon-colored liver; very energetic	Heavily parasitized; pale brownish - colored liver; rather sluggish.

Literature Cited

Bajkov, Alexander
1927. Reports of the Jasper Park Lakes investigations, 1925-1926. Cont. Can. Biol. and Fish. Vol. 3, pp. 379-387.

Berg, Leo S.
1932. Les poissons des eaux douces de l'U.R.S.S. et des pays limitrophes. Part 1, 540 pp.

DeLacy, Allan C.
1941. Contributions to the life histories of two Alaskan charrs, *Salvelinus malma* (Walbaum) and *Salvelinus alpinus* (Linnaeus). [Ph.D. Thesis, Univ. Washington, 114 pp. (Typewritten).]

Dymond, John R.
1932. The trout and other game fishes of British Columbia. Bull. Biol. Board, Canada, Vol. 32, pp. 37-39.

Günther, Albert
1866. Catalogue of the fishes of the British Museum. Vol. 6, 368 pp.

JORDAN, DAVID STARR and B. W. EVERMANN
1896. The fishes of North and Middle America. A descriptive catalogue of the species of fish-like vertebrates found in the waters of North America north of the Isthmus of Panama. Bull. U. S. Nat. Mus. No. 47, part 1, pp. 506-517.
1905. American food and game fishes. Doubleday, Page & Co., pp. 203-219.

JORDAN, D. S., B. W. EVERMANN, and H. W. CLARK
1930. Check list of the fishes and fish-like vertebrates of North and Middle America north of the northern boundary of Venezuela and Columbia. Rept. U. S. Comm. Fish., 1928, part 2, 670 pp.

JUDAY, C., WILLIS H. RICH, G. I. KEMMERER, and ALBERT MANN
1932. Limnological studies of Karluk Lake, Alaska, 1926-1930. Bull. U. S. Bur. Fish., Vol. 47, pp. 407-436.

KENDALL, WILLIAM CONVERSE
1914. The fishes of New England. The salmon family. Part I. The trout or charrs. Mem. Boston Soc. Nat. Hist. Vol. 8, pp. 5-103.

POPOV, A. M.
1933. Fishes of Avatcha Bay on the southern coast of Kamchatka. Copeia, 1933, pp. 59-67.

PRATT, HENRY SHERRING
1935. A manual of land and fresh-water vertebrate animals of the United States (exclusive of birds). P. Blakiston's Son & Co., 2nd ed. pp. 37-50.

REGAN, C. TATE
1911. The fresh-water fishes of the British Isles. Methuen & Co. pp. 72-111.
1914. The systematic arrangement of the fishes of the family Salmonidae. Ann. Mag. Nat. Hist., Series 8, Vol. 13, pp. 405-408.

SCHRENKEISEN, RAY (edited by J. T. Nichols and F. R. LaMonte)
1938. Field book of fresh-water fishes of North America north of Mexico. G. P. Putnam's Sons. pp. 52-58.

SEELEY, HARRY GOVIER
1886. The fresh-water fishes of Europe, a history of their genera, species, structures, habits, and distribution. Cassell & Co. Ltd. pp. 317-328.

SUVOROV, E. K.
1929. Ichthyofauna of the Cheshkaya Bay (Barents Sea). Trans. Inst. Sci. Explor. of the North. Vol. 43, pp. 101-132. [In Russian with English summary.]

YARRELL, WILLIAM
1836. A history of British fishes. John Van Voorst. Vol. 2, pp. 65-75.

THE RESULTS OF PLANTING LEGAL-SIZED TROUT IN THE DEERSKIN RIVER, VILAS COUNTY, WISCONSIN

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ABSTRACT

A creel census was conducted on the Deerskin river to determine the results of stocking trout of legal size. The stocking was done in December and May and consisted of 1,002 brook and 1,621 rainbow trout. A yield of 3,438 trout was obtained. Native fish made up 71 per cent of the catch. Native brook trout supplied the most fishing (50.5 per cent of the total). All stocked fish, especially the larger rainbow planted in December, were inferior in condition and sporting value. There were no reports of either species carrying over to the second season.

During the past two or three decades most attempts to improve fishing in trout streams were based on the planting of hatchery reared fish. At first small fry were planted, later larger fish in the form of fingerlings were stocked. As time progressed the demands for planting fish of legal size grew to a point where if such a program was adopted, it would be necessary to greatly expand the fish rearing facilities. Needless to state, such a program would necessitate a much greater allocation of funds. This study was therefore initiated to determine the value of planting legal-sized fish under the conditions found in some of the Wisconsin streams.

The Deerskin river was selected for this study not only on the basis of its history as a good trout stream in the past;, but also because of its nearness to a populated section and the availability of Civilian Conservation Corps assistance to aid in the stocking and also to supply census clerks. The stream has a total length of 16.9 miles and has an average width of 10 feet. The origin of the stream is as an outlet of Long lake. It has many spring-fed tributary streams. The drainage area is composed of glacial till made up of sand, rocks, and boulders. The stream bottom consists of sand and gravel. There is considerable drop in elevation creating many ripples, rapids, and pools which are, of course, one of the prime prerequisites of a good trout stream.

In general, the results of stocking legal-sized fish show that the planting of such fish in the spring is more beneficial than plantings made in the fall. It is also shown that such fish are quite rapidly depleted. Cobb (1934), using an internal tag, released 15,875 marked legal brown and brook trout in Connecticut streams. A total of 5,403 (33 per cent) recoveries was made. Brook trout planted during the open season usually were depleted within a week but brown trout provided fishing for a little longer period. In Massachusetts, Nesbit and Kitson (1937) found spring planting to be more efficient than fall planting by an average ratio of five to one. Hoover and Johnson

(1938) report a recovery of 76 per cent legal-sized fish in 3 weeks after planting. In a long-range program in Michigan, Shetter and Hazzard (1942) studied plantings of brook trout made in six streams and brown and rainbow in four streams. Approximately 36,000 trout were used in 51 experiments. The recaptures of trout planted in streams ranged from 4.4 to 5.8 per cent for fall planting, 11.3 to 25.5 for spring plantings, and 13.0 to 25.4 per cent for open-season plantings. Brook trout have never been found to carry over to the second season after stocking. A very small number of legal brown and rainbow trout planted in the spring or during the open season were recovered during the second season after their release. For the most part the brook trout were caught out 4 weeks after planting while brown and rainbow trout contributed to the fishing for at least 8 weeks. An average of only 11.8 per cent of the anglers benefited from the plantings. The authors speculate, however, that more anglers might benefit if plantings were made in streams nearer the more densely populated sections of the state.

Stocking of Fish

Table 1 shows the date, number and species of fish that were stocked in the Deerskin river. A total of 1,002 brook and 1,621 rainbow trout or 2,623 fish was planted in the stream. All individuals were marked by the fin clipping method described by Shetter and Hazzard (1940). The stream was stocked at a rate of 154 fish per mile which is more liberal stocking than these workers used. In the Michigan streams averaging 50 feet in width, 100 to 160 fish per mile were planted. The fish were planted at 15 points in the streams. None were planted below the McDermott dam or in the upper two miles of the stream. Two to 3 hours after stocking the fish seemed to spread out so that it was not possible to observe any concentration of planted fish. The entire stream was checked on many occasions to determine the extent of mortality of planted fish but no dead fish were found.

Table 1.—Record of trout planted in the Deerskin river

Species	Number	Size (inches)	Date planted	Fin clipped
Brook trout	802	7-13	December 12, 1940	Right pelvic
Rainbow trout	450	7-15	December 13, 1940	Right pelvic
Brook trout	200	7-13	May 9, 1941	Left pelvic
Rainbow trout	1,171	7-15	May 12, 1941	Left pelvic

The Creel Census

The Civilian Conservation Corps provided the census clerks. Checking stations were established at all strategic points so that practically every fisherman could be intercepted as he left the stream. Census clerks were on duty from 6 a.m. to 9 p.m. daily from May 15, the opening date of the fishing season, to July 23 when the project had to be discontinued because of lack of funds. Additional checking was conducted along the stream to supplant the regular checks but this

Table 2.—Number of native and stocked rainbow and brook trout caught each week of census period

Date	Rainbow trout				Brook trout			
	Native stock	December planting	May planting	Total from both plantings	Native stock	December planting	May planting	Total from both plantings
May 15-21	286	143	220	363	611	171	107	278
May 21-28	99	20	51	71	258	16	18	34
May 29-June 4	60	14	35	49	181	7	9	16
June 5-11	15	27	24	51	106	9	10	19
June 12-18	16	9	5	14	198	10	12	22
June 19-25	11	0	0	0	10	0	0	0
June 26-July 2	71	15	10	25	117	5	5	10
July 3-9	67	3	6	9	114	4	....	4
July 10-16	61	8	3	11	86	4	2	6
July 17-23	18	8	4	12	58	0	1	1
Total	704	247	358	605	1,739	226	164	390
Per cent total yield	20.5	7.1	10.7	17.8	50.5	6.5	4.7	11.2

type of census was kept at a minimum so as not to bother fishermen until they had completed their efforts.

The numbers of native and artificially stocked fish caught each week during the census period is given in Table 2. The greatest number of fish was taken during the first week of the open season. It is noted that during the first and fourth weeks the catch of marked rainbow trout exceeded the native stock. During the rest of the period the unmarked fish in the creels were always more numerous than the marked fish. While the catches dropped off considerably after the first week, the brook trout provided much better fishing than did the rainbow trout.

A total of 3,438 fish was removed from the stream during the census period. The native stock made up 71 per cent (2,443 fish) and the planted fish 29 per cent (995 fish) of the yield. Native brook trout supplied most of the fish, 1,739 or 50.0 per cent, while the established population of rainbow contributed 704 or 20.5 per cent. Of the 995 stocked fish that were found in the creels, 605 were rainbow trout and 390 were brook trout. In view of the fact that only approximately 13 miles of the stream is fished for trout to any extent, the yield was approximately 264 fish per mile, the native fish being taken at the rate of 188 per mile. Considering further that the census was conducted only until July 23, it is reasonable to expect that fishing for the balance of the season (to September 7) would produce enough native stock to bring the total yield up to 200 or more fish per mile.

Table 3 contains a summery of the recapture of legal-sized trout planted. Considering first the brook trout, it is seen that 82 per cent of those planted in May were recovered while only 28.2 per cent of those planted in December were taken by anglers. With respect to the rainbow trout, the recovery was 48.4 per cent for the December planting and 30.5 pr cent for the may stocking. As for the returns on all fish released, 995 or 37.5 per cent of the 2,623 planted fish were recovered.

Table 3.—Summary of recapture of legal size trout planted

Species	Date released	Number released	Number recaptured	Per cent recaptured
Brook trout	December, 1940	802	226	28.2
Brook trout	May, 1941	200	164	82.0
Rainbow trout	December, 1940	450	247	48.4
Rainbow trout	May, 1941	1,171	358	30.5
Total		2,623	995	......

The rainbow trout that had been planted in December were very emaciated upon recapture. The rainbows, 10 inches and longer, seemed to have lost much more weight than those under that size. On the first day of the open season, 8 of the larger rainbow trout (from the December stocking) were found on the bank of the stream. Upon investigation it was learned that several fishermen had caught their limit and had discarded those fish in order to replace them in their creels with fish in better condition. With reference to the sporting

quality of the fish, fishermen stated they could identify native or stocked fish as soon as they "took the hook." A general lack of fight was noted in all planted fish but was most evident in the larger rainbow trout.

While no regular or routine census was conducted during the next season (1942), the senior author and others checked fishermen on the stream frequently for the recovery of marked fish. Not a single record of the capture of a marked fish could be found. This is in agreement with the findings of other investigators that there is very little or no carry over of stocked fish to the next season.

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Summary

1. Legal-sized rainbow and brook trout were marked and planted in the winter and spring in the Deerskin river, Vilas county, Wisconsin, prior to the 1941 open season.

2. A creel census was conducted from May 15 to July 23, 1941.

3. A total of 3,438 trout were removed from the stream during the creel census period. The stocking efforts contributed 995 fish or 29.0 per cent of the total yield.

4. The recapture of 995 of the 2,623 marked trout released gives a return of 37.5 per cent of the fish planted.

5. The stocked fish, especially the larger rainbow trout planted in December, were inferior in condition and sporting qualities as compared to the native stock.

6. There were no reports of marked fish having been caught during the following season (1942).

Literature Cited

Cobb, Eben W.
1934. Results of trout tagging to determine migrations and results from plants made. Trans. Am. Fish. Soc., Vol. 63, pp. 308-318.

Hoover, Earl and M. S. Johnson
1938. Migration and depletion of stocked brook trout. Trans. Am. Fish. Soc., Vol. 67, pp. 224-227, 3 figs.

Nesbit, Robert A., and J. Arthur Kitson
1937. Some results of trout tagging in Massachusetts. Copeia, No. 3, pp. 168-172.

Shetter, David S. and Albert S. Hazzard
1940. Results from plantings of marked trout of legal size in streams and lakes of Michigan. Trans. Am. Fish. Soc., Vol. 70, pp. 446-468.
1942. Planting "keeper" trout, Michigan Conservation, Vol. 11, No. 4, pp. 3-5.

ORGANIC MATERIALS AS FERTILIZERS FOR FISH PONDS[1]

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ABSTRACT

The production of fish in ponds can be increased by the use of organic fertilizers such as cottonseed meal and soybean meal, and productivity can be further increased by the addition of superphosphate to these meals. From the standpoint of fish production alone, such organic materials are worthy of consideration as fertilizers for fish ponds.

There are certain limitations to the use of both cottonseed meal and soybean meal, alone or in combination with superphosphate, however. In experiments, dense growths of filamentous algae developed in ponds fertilized with the above materials. Excessive amounts of filamentous algae are objectionable in ponds; they interfere with fishing and harbor mosquito larvae and pupae. In addition, although cottonseed meal stains water brown, ponds fertilized with this material are usually too clear for best fishing.

Some means must be found for overcoming the objectionable features of organic fertilizers before they can be generally recommended for use in ponds, even though they do increase productivity.

INTRODUCTION

Fish-culturists agree that the production of fish in ponds usually can be increased by fertilization. There are two general sources of fertilizing materials for use in ponds. Organic materials such as cottonseed meal, soybean meal, hays, and manures constitute one source, and inorganic materials such as nitrate of soda, ammonium sulphate, superphosphate, muriate of potash, and standard mixtures of such materials constitute the other.

In the United States, much of the early work on pond fertilization was concerned with increasing the productivity of hatchery ponds, especially those producing largemouth black bass for stocking purposes. Wiebe (1929) reported the use of superphosphate, a mixture of soybean meal and superphosphate, shrimp bran, and sheep manure in ponds at Fairport, Iowa. Davis and Wiebe (1930) discussed the use of fertilizers in bass rearing ponds and reported that ponds fertilized with 700 pounds of soybean meal per acre gave the greatest production of black bass fingerlings.

Meehean (1933) compared the use of soybean meal, cottonseed meal, and sheep manure for the production of fish-food organisms. Soybean meal produced 10 to 30 times as many organisms as sheep manure and cottonseed meal produced 6 to 7 times as many as soybean meal. He also fertilized ponds with various amounts of cottonseed meal and

[1]Published with the approval of the Director of the Alabama Agricultural Experiment Station.

manure. The largest yield of bass fingerlings was obtained from the use of approximately 1,000 pounds of cottonseed meal per acre applied over a period of 17 weeks.

Hogan (1933) fertilized ponds with cottonseed meal and superphosphate (in the ratio, 2:1), and cottonseed meal and commercial "6-8-6" (in the ratio, 2:1). He concluded that the mixture of cottonseed meal and superphosphate was superior to the mixture of cottonseed meal and "6-8-6" for rearing bass fingerlings. He suggested that the cottonseed meal served as a direct food for the bass fingerlings as well as a pond fertilizer.

Organic fertilizers continue to be used in hatchery ponds as evidenced by Meehean's (1939) recommendation of cottonseed meal for fertilizing bass rearing ponds.

During recent years, much attention has been directed toward the fertilization of ponds for the improvement of fishing. In the Southeastern States, at least, inorganic fertilizers have been largely used in fish ponds. Swingle and Smith (1942) reported a 4- or 5-fold increase in fish production from the use of inorganic fertilizers.

Although inorganic fertilizers have given extremely satisfactory results in fish ponds, the present national emergency has caused a marked reduction in the amount of inorganic nitrogen available for all fertilizer purposes and it is probable that the shortage may be further accentuated. In addition, there probably will be a marked increase in the amount of organic nitrogenous materials as a result of the expansion in the production of oil crops. It, therefore, seems pertinent at this time to determine the value and limitations of organic fertilizers.

Evaluation of Organic Fertilizers

For any material to be acceptable as a fertilizer for fish ponds, it must fulfill the following requirements:

1. It must increase the production of fish.
2. It must improve the "fishability" of the pond by:
   a. Discouraging the growth of filamentous algae;
   b. Discouraging the growth of noxious waterweeds other than filamentous algae;
   c. Increasing "cloudiness" of the water, thereby increasing the frequency of "biting."

Experiments dealing with fertilizers for use in fish ponds have been in progress at the Alabama Agricultural Experiment Station since 1934. Both organic and inorganic fertilizers have increased fish production. The results from the use of inorganic fertilizers have been reported previously and will be mentioned only when comparisons seem desirable.

In the first experiment in which organic fertilizers were included, one pond was fertilized with cottonseed meal, a second with cottonseed meal and superphosphate, and a third with commercial poultry laying

mash (Table 1). The ponds were stocked with bluegill fingerlings (*Lepomis macrochirus*) in May and were drained in November. The data in Table 1 show that all fertilizer treatments greatly increased productivity. The addition of heavy applications of superphosphate to cottonseed meal almost doubled the production as compared to that from cottonseed meal alone.

Table 1.—Results from the use of cottonseed meal, cottonseed meal plus superphosphate, and poultry laying mash as fertilizers for fish ponds

Pond No.	Fertilizer: Kind	Number of applications	Total applied (pounds per acre)	Carrying capacity[1] (pounds per acre)
1	None	0	0	92
2	Cottonseed meal	22	2,860	295
3	Cottonseed meal	22	2,860	......
	16 per cent superphosphate	4	5,540	577
4	Poultry laying mash	22	2,860	451

[1]The ponds were stocked with bluegill fingerlings in May and were drained in November.

In this experiment, the fertilizers were applied at rates that probably should be considered uneconomical, but an effort was made to obtain maximum production. In spite of the extremely high rates of application of organic fertilizers, no fish died from lack of oxygen, and chemical analyses indicated that the dissolved-oxygen content of the pond water was never reduced to a critical level.

In a second experiment, separate ponds were fertilized with cottonseed meal, cottonseed meal and superphosphate, soybean meal, and soybean meal and superphosphate (Table 2). The plan of the experiment did not require that a stipulated total amount of fertilizer be applied to any pond or that all ponds be fertilized at the same rate, but rather that each pond be fertilized whenever an application seemed advisable. The ponds were stocked in February and drained in November; thus the growing season was somewhat longer than in the preceding experiment. The data in Table 2 substantiate those in Table 1 in showing that all fertilizers used increased fish production as compared to the "no-fertilizer" treatment. Apparently, the addition of superphosphate to the organic fertilizers increased the production of bluegills. A direct comparison of the value of cotonseed meal and soybean meal cannot be made on the basis of the results from this experiment. Although fertilizers containing soybean meal produced higher fish yields than did those containing cottonseed meal, greater amounts of soybean meal were applied.

In a third series of experiments, 15 ponds were fertilized with cottonseed meal, soybean meal, peanut meal, and 3:1 and 6:1 mixtures of each meal and superphosphate; each meal or mixture was applied to separate ponds at monthly and semi-monthly intervals from May until October. All fertilizer treatments increased the carrying capacity of

Table 2.—Results from the use of cottonseed meal, soybean meal, and mixtures of these meals and superphosphate as fertilizers for fish ponds

Pond No.	Fertilizer			Carrying capacity[1] (pounds per acre)
	Kind	Number of applications	Total applied (pounds per acre)	
1	None	0	0	130
2	Cottonseed meal	10	975	423
3	Cottonseed meal	8	780	478
	16 per cent superphosphate	....	325	....
4	Soybean meal	15	1,500	520
5	Soybean meal	9	870	615
	16 per cent superphosphate	....	365	....

[1]The ponds were stocked with bluegill fingerlings in February and were drained in November.

the ponds for bluegills over the unfertilized controls, and in all ponds except one the increase amounted to 100 per cent or more. As in previous experiments, the addition of superphosphate to the seed meals tended to increase the productivity. In this experiment, fertilizers containing soybean meal gave greater fish productions than did those containing the other seed meals, even when equal amounts were applied.

Thus, it is evident that the seed meals, alone and in combination with superphosphate, fulfill requirement (1). In general, all forms of organic fertilizers tested at Auburn have increased fish production. From this standpoint, these materials are worthy of consideration as fertilizers for fish ponds.

The principal limitations to the use of organic fertilizers arise from the fact that these materials tend not to fulfill requirements (2a) and (2c). There is a general tendency for filamentous algae to develop in ponds fertilized with organic fertilizers. It is practically impossible to fish for bluegills with hook and line in a pond in which the bottom is covered with filamentous algae. These algae also foul plugs and flies and make casting unsatisfactory. In addition, filamentous algae in shallow water protect mosquito larvae and pupae, and present a mosquito hazard. Where malaria occurs, this condition cannot be tolerated, and it is doubtful whether mosquitoes add to fishing pleasure elsewhere.

Some experimental evidence of the tendency of organic fertilizers to encourage the growth of filamentous algae can be given. An experiment was planned in which a half-acre pond was to be fertilized with a 3:1 mixture of cottonseed meal and superphosphate at the rate of 100 pounds per acre per application. After two applications in January and February, however, such a dense growth of filamentous algae developed that fishing became almost impossible and the use of the fertilizer mixture was discontinued. Four applications of nitrate of soda were made during March, April, and May in an effort to control the filamentous algae. After the growth of filamentous algae was sup-

pressed, two applications of the original mixture were made in June and July. Filamentous algae reappeared in the pond and grew during the remainder of the season even though no more fertilizer was applied.

Soybean meal, alone or with superphosphate, appeared less likely to support filamentous algae and more likely to encourage phytoplankton than did cottonseed meal in the earlier experiments. Consequently, a mixture of soybean meal and superphosphate (6:1) was used during 1941 in 2 quarter-acre ponds stocked with largemouth black bass (*Huro salmoides*) and bluegills. Contrary to previous experience, the mixture of soybean meal and superphosphate, even in moderate amounts, induced a heavy growth of filamentous algae which grew throughout the season. The masses of algae were so dense that it was impossible to obtain the usual monthly seining records from these ponds. Furthermore, although the ponds were drained in November and a new experiment initiated in which inorganic fertilizers were used, the effects of the previous fertilizer treatment appeared to carry over, and dense growths of filamentous algae developed in the ponds in the spring of 1942.

Another experiment was planned in 1941 in which the mixture of soybean meal and superphosphate was to be used in a 2-acre pond stocked with largemouth black bass, bluegills, and golden shiners (*Notemigonus crysoleucas*). A dense growth of filamentous algae developed in this pond also, making it advisable to substitute an inorganic fertilizer for the mixture. The filamentous algae disappeared after the substitution and were replaced by phytoplankton.

Since cottonseed meal and soybean meal are conducive to the growth of filamentous algae, it would appear that they might be substituted for inorganic fertilizers in the program developed by Smith and Swingle (1942) for the control of certain underwater weeds; these materials have not been tested as yet for this purpose, however. If the suggested substitution could be made, then it could be considered that these materials would fulfill requirement (2b); if filamentous algae continued to grow in the pond after the weeds were destroyed, however, the advantage gained by the destruction of the weeds would be nullified to a large extent.

The organic fertilizers do not fulfill requirement (2c). As already indicated, the development of filamentous algae offers a definite detriment to fishing. In addition, it is generally known that warm-water fish do not bite readily in crystal-clear water; recognition of this fact leads many fishermen to fish clear waters at night. It is believed that one of the reasons that fish bite readily in ponds fertilized with inorganic fertilizers is that the cloudiness of the water caused by plankton prevents the fish from seeing the line attached to the bait. A comparison of annual catches from a pond fertilized with an inorganic fertilizer and another fertilized with cottonseed meal and superphosphate should be of interest in this connection.

One pond was fertilized with an inorganic fertilizer which main-

tained a good growth of phytoplankton. The other pond was fertilized with cottonseed meal and superphosphate; this fertilizer produced filamentous algae that interfered with fishing during part of the season, and, although stained by the cottonseed meal, the water was so clear as to make fishing unsatisfactory during most of the year. No difficulty was encountered in obtaining cooperators to fish the pond fertilized with the inorganic fertilizer, but so few guests wanted to fish the other pond a second time that the project leaders were forced to do the fishing. Fishermen removed nearly one-half (260 pounds per acre) of the total weight of fish from the pond fertilized with inorganic fertilizer, but they removed only about one-sixth (100 pounds per acre) of the total weight from the one fertilized with the organic fertilizer. Since both ponds had a high carrying capacity, the differences in total annual catch between the two ponds can best be ascribed to differences in "fishability."

From the foregoing discussion, it is evident that, although organic fertilizers increase the productivity of fish ponds, some means must be found by which the objectionable features resulting from the use of such materials can be eliminated before they can be recommended as fertilizers for ponds. Experiments are now in progress at this Station in which mixtures of organic and inorganic fertilizers are being tested in an effort to develop a method by which the organic fertilizers may be used satisfactorily.

Literature Cited

Davis, H. S., and A. H. Wiebe
1931. Experiments in the culture of black bass and other pondfish. Rep. U. S. Comm. Fish. for 1930, pp. 177-203.

Hogan, Joe
1933. Experiments with commercial fertilizers in rearing largemouth black bass fingerlings. Trans. Am. Fish. Soc., Vol. 63, pp. 110-119.

Meehean, O. Lloyd
1933. The role of fertilizers in pondfish. Trans. Am. Fish. Soc., Vol. 63, pp. 103-109.

Smith, E. V. and H. S. Swingle
1942. The use of fertilizer for controlling several submerged aquatic plants in ponds. Trans. Am. Fish. Soc., Vol. 71 (1941), pp. 94-105.

Swingle, H. S. and E. V. Smith
1942. Management of farm fish ponds. Ala. Agric. Expt. Sta., Bul. 254, 23 pp.

Wiebe, A. H.
1929. The effects of various fertilizers on plankton production. Trans. Am. Fish. Soc., Vol. 59, pp. 94-105.

THE EFFECT OF IMPOUNDMENT ON FISHING INTENSITY IN SEVERAL T.V.A. WATERS[1]

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ABSTRACT

Fisherman counts on two pre-impoundment areas in the Tennessee Valley are compared with similar counts on completed reservoirs. On the basis of these counts it is estimated that fishing in the Cherokee Reservoir area will increase almost 50-fold 5 years after impoundment; on the Watts Bar Reservoir area fishing is expected to increase 10- or 15-fold several years after impoundment.

INTRODUCTION

Netting with hoop nets in that portion of the Holston River which will be covered by Cherokee Reservoir, and in that portion of the Tennessee River which will become Watts Bar Reservoir, indicates that in 1941 fish were fewer in the rivers than in Wheeler Reservoir, several years after the latter was impounded.[2] Impounding the water not only increases greatly the acreage of fishing water, but for a period of years at least, also increases the number of fish per acre. It is apparent, too, that the reservoirs support much more fishing than those portions of the Tennessee and its major tributaries which are still unimpounded. This discussion is intended to demonstrate in a general way the increase in fishing intensity resulting from impoundment.

Inquiries concerning the intensity of fishing in T.V.A. waters were made in 1940 on one storage reservoir (Eschmeyer, 1942) and on four run-of-the-river reservoirs (Tarzwell, 1942). During the following summer fishermen counts were made on the Holston and Tennessee Rivers in areas to be covered by Cherokee and Watts Bar Reservoirs, respectively. The former will be a storage-water similar to Norris; the latter will be the run-of-the-river type. The two areas are considered separately below. In both areas the counts were made in the same manner as the counts on the reservoirs in 1940 and the methods of computation were likewise similar.

Eventually, comparisons of fishing intensity will be made for these same waters; for example, a comparison will be made of the fishing on the Holston River before impoundment and on Cherokee Reservoir several years after impoundment. For the present, comparisons are made with reservoirs of similar type, which are already established.

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[1]Published with permission of the Tennessee Valley Authority.
[2]Smith, Charles G. and Lawrence F. Miller. A comparison of the hoop-net catch on several waters in the Tennessee Valley before and after impoundment. (To be found elsewhere in this volume.)

The counts were made by Edwin Eastwood, Merrill White, and Jack Mahaney of the Biological Readjustment Division staff. The men invariably travelled by boat, using an outboard motor where possible.

Cherokee Reservoir

Cherokee Reservoir will impound the Holston River from a point near Rogersville, Tennessee, to the dam site located near Jefferson City, Tennessee, a distance of about 59 miles by channel. During June through September of 1941, 16 counts of fishermen were made on the Holston River from Morristown to the dam site, a distance of 23 miles, or about 39 per cent of the length of the reservoir. The counts were made at various times of day, on various days of the week, and on the dates set for them, regardless of the weather conditions or the stage of the river. In these respects the counts were similar to those made on the reservoirs the previous year. On the river, however, all counts were made in one direction, downstream, because of the difficulty of moving upstream, especially at times of low water level. The average number of fishermen counted, per trip, is recorded in Table 1. The estimated average number of fishing trips per month, based on the counts, is indicated in Table 2.

Table 1.—Average number of fishermen per count in the Cherokee Reservoir area from Morristown to dam site, 1941

Month	Number of counts	Boat	Bank	Set-line	Net
June	5	3.4	0.8	0.6	....
July	3	1.3	1.0	....	....
August	5	1.6	4.2	0.4	0.6
September	3	0.3	0.7	....	....

The monthly estimates of fishing intensity are computed by multiplying the average number of fishermen seen by two (because the average fishing trip is about a half-day and it is assumed therefore that only half the fishermen are seen by those making the count) and by the number of days per month. It is assumed that the upper portion of the area is fished with the same intensity as the lower 23 miles. The entire length is 2.6 times the length studied, and the number of fishing trips for the whole area is therefore about 2.6 times the number from Morristown to the dam site. The figures in Table 2 are for the entire reservoir area. It need hardly be stated that the figures are to be considered only approximate.

Table 2.—Estimated number of fishing trips, in the Cherokee Reservoir area, 1941[1]

Month	Boat	Bank	Set-line	Total
June	530	125	94	749
July	210	161	....	371
August	258	677	64	999
September	47	109	....	156
Total	1,045	1,072	158	2,275

[1]Average number counted × 2 × days per month × 2.6 (see text).

Cherokee Reservoir will compare with Norris in many respects. Both are storage reservoirs with extensive fluctuation, and both are on streams of similar size tributary to the Tennessee River. The reservoirs have adjacent drainage basins of about equal size (Norris 2,912 square miles, and Cherokee 3,428 square miles). Norris Reservoir has a much longer shoreline, largely because it floods two rivers (Clinch and Powell), whereas Cherokee floods only one river, the Holston. Elevations at spillway level are comparable (Norris 1,020 feet; Cherokee 1,043 feet). Norris is somewhat larger than Cherokee, having an area of about 34,200 acres at spillway crest (elevation, 1,020 feet), and about 40,200 acres when filled to the top of the gates (elevation, 1,034 feet). Cherokee will have an area of about 19,200 acres at spillway crest (elevation, 1,043 feet), and 32,200 acres when filled to the top of the gates (elevation, 1,075 feet). The "normal" summer level of Norris, however, is spillway level (34,200 acres) and the "normal" summer level of Cherokee is to the top of the gates (about 32,200 acres). The two therefore are comparable as to size. Both dams are about the same distance from Knoxville, the only large community in this general vicinity.

Because of the similarity of the two reservoirs, the fishing intensity on Cherokee may be expected to compare with that on Norris. If it follows the same trend, fishing on Cherokee during its fifth year of impoundment may be expected to total about 100,000 individual fishing trips in the 4-month period following June 1—a very decided increase over the estimated 2,275 fishing trips on the river during this period in 1941 (Table 3). The increase in sport fishing will probably be even greater because about three-fourths of the Norris fishing was

Table 3.—Comparison of the number of fishing trips in the Norris Reservoir area, 1940, and the Cherokee Reservoir area, 1941

Month	Norris[1]	Cherokee
June	61,100	749
July	27,000	371
August	17,100	999
September	9,500	156
Total	114,700	2,275

[1]June figure for Norris includes also May 30, opening day of the season, and May 31.

boat fishing, much of it with artificial bait. On the Holston River less than half the fishing was by boat.

Watts Bar Reservoir

The method of counting fishermen on the Tennessee River in the area to be covered by Watts Bar Reservoir was similar to that employed on the Holston River, except that the count covered 86 per cent of the length of the stream (from Loudon to the dam site). For convenience, the area examined was divided into five sections. At times

the entire 62 miles were covered in a single day; at other times a part of it (Loudon to Rockwood) was covered in one day and the remainder on the next day. Thus there was considerable variation in the time at which any one point was checked. In June, several sections were seen three times and several other sections five times; during other months the same number of counts were made on all sections (Table 4).

Table 4.—Average number of fishermen per count in the Watts Bar Reservoir area from Loudon to dam site, 1941

Month	Number of counts	Boat	Bank	Set-line	Net
June	3-5	14.4	15.4	8.5	0.4
July	5	5.6	6.2	0.6	....
August	4	6.5	5.1	1.0	....
September	3	7.0	1.9	3.4	0.7

It is estimated that there were about 5,255 fishing trips on Watts Bar Reservoir area (main stream only) during the 4-month period (Table 5), or about twice the amount computed for the Cherokee Reservoir area. Here, as on the Cherokee, boat and bank fishing were about evenly divided. Set-line fishing was practiced much more extensively on the Tennessee than on the Holston River.

Watts Bar Reservoir, like Wheeler, Wilson, and other main-stream reservoirs, will differ decidedly from Cherokee, Norris, and other storage reservoirs. The main-stream reservoirs have small fluctuations and a large discharge in proportion to the volume of water; storage reservoirs have a large yearly fluctuation and a small discharge in proportion to volume. The trend in fishing on Watts Bar Reservoir may be expected to follow that for Wilson and Wheeler Reservoirs. The reservoir will be much larger than Wilson but much smaller than Wheeler (Wilson 16,000 acres, Wheeler 67,000 acres, and Watts Bar 37,000 acres). All three bodies of water are on the Tennessee River, although Watts Bar Reservoir lies well above the other two, and is separated from Wheeler by Chickamauga, Hales Bar, and Guntersville Reservoirs, a distance of almost 200 miles.

Table 5.—Estimated number of fishing trips in the Watts Bar Reservoir area, 1941[1]

Month	Boat	Bank	Set-line	Total
June	1,002	1,072	592	2,666
July	403	446	43	892
August	467	367	7	841
September	487	132	237	856
Total	2,359	2,017	879	5,255

[1]Average number counted × 2 × days per month × 1.16 (see text).

Because of the difference in size, fishing intensity on Watts Bar is compared with fishing on Wheeler and Wilson on a basis of fishing trips per 1,000 acres. Tarzwell and Miller[3] estimated 2,039 individual

[3]Tarzwell, Clarence M. and Lawrence F. Miller. A report on the measurement of fishing intensity on TVA reservoirs. (To be found elsewhere in this volume.)

trips per 1,000 acres on Wilson Reservoir for the 4-month period beginning June 1, 1940, in the seventeenth year of impoundment. Their estimate was 3,104 fishing trips per 1,000 acres on Wheeler for the same period, in its fourth full year of impoundment.

The fishermen counts on Watts Bar area were made only on the main stream, not on its several tributaries of fishable size. After impoundment these tributaries (Clinch, Emory, and Piney Rivers, and White and Caney Creeks) will flood about 12,400 acres. Watts Bar Reservoir, exclusive of these areas, will have an area of about 25,500 acres (elevation, 741 feet), the figure used for comparisons made in

Table 6.—Comparison of the number of fishing trips, per 1,000 acres of water in the Wilson and Wheeler Reservoirs, 1940, and in the Watts Bar Reservoir area, 1941

Month	Wilson[1]	Wheeler	Watts Bar
June	938	1,000	104
July	275	781	35
August	438	801	33
September	388	522	34
Total	2,039	3,104	206

[1]Not including the fishing in the tail waters at the head of Wilson and Wheeler Reservoirs. The estimated number of fishermen on these two tail waters combined, for the 4-month period, was 23,700—far more trips than in the entire Watts Bar Reservoir area.

Table 6. It will be noted that if fishing intensity on this reservoir follows the trend on Wilson and Wheeler Reservoirs, it will increase from about 200 trips per 1,000 acres to 2,000 or 3,000 trips per 1,000 acres during the 4-month fishing period. Fishing in this reservoir may be expected to increase, roughly, 10- to 15-fold after several years of impoundment. It is encouraging to note that Wilson Reservoir in its seventeenth year was still heavily fished, suggesting that the main-stream reservoirs may possibly continue to support moderately heavy fishing indefinitely, or at least for a long period.

Literature Cited

Eschmeyer, R. W.
1942. The catch, abundance, and migration of game fishes in Norris Reservoir, Tennessee, 1940, Jour. Tenn. Acad. Sci., Vol. 17, No. 1, pp. 90-115.

Tarzwell, Clarence M.
1941. A second season of creel census on four Tennessee Valley Authority reservoirs. Trans. Sixth N. Am. Wildlife Conf., pp. 202-221.

THE AGE, GROWTH, AND BATHYMETRIC DISTRIBUTION OF REIGHARD'S CHUB, *LEUCICHTHYS REIGHARDI* KOELZ, IN LAKE MICHIGAN

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Abstract

Reighard's chub has come to be one of the most important species of the group since the serious decline in abundance of the larger representatives of the genus *Leucichthys* in Lake Michigan. An understanding of the biology of as many species of chubs as possible is essential if further depletion and the collapse of the fishery are to be prevented.

The age and growth of 331 individuals taken in 1932 were determined. Each of the other phases of the study is based on more than 5,000 specimens collected during the three years, 1930-1932.

Reighard's chub occurred most abundantly, when not spawning, in depths of 20 to 60 fathoms where the temperature of the water ranged from 38.8 to 40.6° F. It was taken at all depths where the nets were set from 12 to 97 fathoms, and in water that varied from 34.7 to 50.6° F. The abundance on the east shore was seven times that on the west shore and between two and three times that in the upper part of the lake. The data indicate the existence of separate populations on the two shores. The greater exploitation with smaller meshes in the western part of the lake probably accounts for the relative scarcity in those waters. Ecological factors are considered the probable cause of the lesser abundance in the upper lake. Spawning occurs during May and June at depths of 20 to 79 fathoms, over a wide variety of bottom materials at temperatures of 38.8 to 40.5° F.

Age-group IV dominated in the samples of fish whose ages were determined and made up 50.2 per cent of the total. Age groups V and III were the next largest groups in that order. Growth in length was most rapid during the first year of life. Growth in weight was most rapid during the first three years with the annual increment in weight about the same in each of those years. The sexes grew in both length and weight at approximately the same rate. Growth compensation occurs in the *reighardi* of Lake Michigan, but the first year differences were not removed entirely by the time of capture in the fifth year.

The weight of the fish in the combined samples increased as the 2.468 power of the length. No relationship between condition (K) and rate of growth could be demonstrated. Condition (K) was better in 1931 than in either 1930 or 1932 and usually was better in 1930 than in 1932. The seasonal changes in relative heaviness followed the same general trend irrespective of the sex or stage of maturity of the fish. The females lost 8 per cent of their weight in spawning, but no loss of weight could be demonstrated for the males.

The females were always strongly dominant in the samples except during May and June 1931 and May 1932 when the sexes occurred in about equal numbers. The relative abundance of the sexes did not change materially in age-groups II to V. There were no males assigned to age-groups VI and VII.

Introduction

The present study is a part of the extensive investigation of the chub fishery of Lake Michigan conducted jointly by the former U. S.

Bureau of Fisheries and the Michigan and Wisconsin Departments of Conservation during the years 1930-1932.

With the serious decline in abundance of the larger species of chubs, Reighard's chub has come to be one of the most important species of the group in the commercial catch of Lake Michigan. The species makes an acceptable "smoked fish" (the principle form in which all of the chubs are offered for human consumption) but largely because of its small size (9½ to 12 inches) it can not command the best price. The growing importance of the less valuable forms in the catches due to the decline of the larger species emphasizes the necessity of obtaining an understanding of the biology of as many species in the group as possible so that effective measures may be taken to prevent further depletion and the collapse of the fishery.

Since the commercial fishermen now are dependent upon the less valuable species, a serious depletion of the present stocks could be disastrous. The gradual decline in the yield of all chubs in Lake Michigan from 6¼ to 4 million pounds from 1934 to 1939 which was followed by the extremely low catch of just more than 1½ million pounds in 1940 perhaps suggests that the depletion of the last of the species of chubs is well underway.

Specific recommendations for conservation are omitted from this paper because the intermingled populations of the several species makes it necessary to formulate regulations for the group as a whole rather than for individual species. Final recommendations must await the completion of studies on the other species. Studies on two of those species are now underway.

The term "chub" is used on Lake Michigan to designate any one of seven species of the genus *Leucichthys*. The species present in Lake Michigan are: *alpenae* (the longjaw), *hoyi* (the bloater), *johannae* (the chub), *kiyi* (the kiyi), *nigripinnis* (the blackfin), *reighardi* (Reighard's chub), and *zenithicus* (the short-jawed chub). The most easily observed characters used to identify *reighardi* are: The decidedly terete or cylindrical body; the underslung, short lower jaw; the nearly vertical position of the front part of the upper jaw (premaxillaries); the short snout; the black pigment usually conspicuous at the tips of the upper and lower jaws, and frequently prominent on the body and abdominal fins; and the short paired fins. The *reighardi* population in northern Lake Michigan (north of a line from Washington Island, Wisconsin, to Frankfort, Michigan) was considered by Koelz (1929) to represent a distinct race but was not named. Reighard's chub most closely resembles the short-jawed chub (*zenithicus*) since these two species are the only ones in the group with the underslung, short lower jaw. *L. reighardi* has a wider body, usually much more pigment about the mouth, shorter pectoral fins, and a shorter snout than *L. zenithicus*. Since Reighard's chub spawns in May and June and the short-jawed chub spawns in November, the stage of development of the sex organs often aids in separating these two

species. (See Koelz, 1929, for more detailed descriptions and comparisons.)

Nothing has been published concerning the feeding habits, migrations, age, growth, and actual abundance of *reighardi* in Lake Michigan. The only observations on the other phases of the natural history of the species in Lake Michigan are those of Koelz. Pritchard (1931) studied the growth, food, and age at spawning of the *reighardi* in Lake Ontario.

I am indebted to Dr. John Van Oosten, in charge of Great Lakes Fishery Investigations, U. S. Fish and Wildlife Service, and to Dr. Ralph Hile, Associate Aquatic Biologist, U. S. Fish and Wildlife Service, for valuable suggestions and for critically reviewing the manuscript. The data and materials upon which this paper is based were collected by and under the field supervision of Dr. H. J. Deason, Special Assistant to the Director of the U. S. Fish and Wildlife Service, who was assigned to the Lake Michigan investigation during the years 1930-1932. Dr. Deason also computed the factors for converting standard length to total length.

Materials and Methods

The data were obtained in connection with the fishing of experimental gill nets from the U. S. Fishery Vessel *Fulmar* during 1930, 1931 and 1932. Five sizes of mesh (2⅜, 2½, 2⅝, 2¾, and 3 inches, stretched measure as manufactured) were used in the linen gill nets fished in 1930 and 1931, except in Green Bay during late September and early October 1930, when only the three smaller sizes were used. Only the three intermediate sizes were employed in 1932 except that the 2⅜-inch-mesh nets also were used in Green Bay at the beginning of the season. Each net was 510 feet long and 5 feet deep. All the nets were set on the bottom. The age was determined and the growth computed for 331 individuals (95 taken June 14, 1932, off Manistique, Michigan, and 236 taken August 13, 1932, off Charlevoix, Michigan). (Figure 1, open circles, shows exact locations.) The length-weight relationship was determined for 5,671 specimens (506 in 1930, 2,213 in 1931, and 2,952 in 1932) taken at many localities distributed generally throughout the shallower waters of the lake (Figure 1, solid circles). The length-frequency distribution was obtained for 7,571 fish taken during the three years. The sex of 8,449 individuals was determined. (On some dates sex and stage of maturity were determined without obtaining data on length and weight.) Only three fish were sexually immature or nonspawning: Two males with standard lengths of 210 and 250 millimeters (9.8 and 11.6 inches, total length), and one female with a standard length of 242 millimeters (11.3 inches, total length). All of the 1930 and 1931 collections were from localities south of a line extending from Kewaunee, Wisconsin, to Frankfort, Michigan, with the exception of those taken in late September and early October

1930, which were from Green Bay, and all of the 1932 collections were obtained north of that line.

Length measurements were obtained from fresh specimens in the field by holding a steel tape graduated in millimeters as nearly parallel to the long axis of the body as possible. The weights were obtained from fresh individuals, and were recorded to the nearest one-fourth ounce in 1930 and in part of 1932, and to the nearest one-tenth ounce in 1931 and in the remainder of 1932. The fish scales were mounted on glass slides following the method of Van Oosten (1929), and were examined at a magnification of $\times$ 40.7. Ages are expressed in roman numerals equivalent to the number of annuli found on the scales. Thus, a fish assigned to age-group III was in its fourth year of life when captured. The calculated lengths were obtained by the direct-proportion method of computation employing the diameter measurements of the scales.

Bathymetric Distribution and Abundance

Koelz (1929) discussed the bathymetric distribution of Reighard's chub in Lake Michigan as determined from 43 lifts mostly made by commercial fishermen, 23 of which lifts were from localities not fished by the "*Fulmar.*" He concluded that the depth of maximum abundance was between 30 and 60 fathoms. The species ranged between 6 and 90 fathoms when not spawning, but those depths were stated not to be the outside limits of the range. Koelz found the juveniles to be common in bait nets (1½-inch mesh) set in depths of 26 to 40 fathoms.

Data on the bathymetric distribution and abundance of Reighard's chub in Lake Michigan during 1930-1932 are presented in Table 1 which gives the average number of fish taken per gang of nets each month during the collecting season each year from each 10-fathom interval of depth of water, and the range of depth in which the nets were set. The mean of the depths at the ends of a gang of nets was used as the depth in which that gang fished. The averages in the upper half of the table are based on the catch from gangs of five 510-foot nets (one net each with meshes of 2⅜, 2½, 2⅝, 2¾, and 3 inches) whereas those in the lower half are on the basis of three nets per gang (one net each with meshes of 2½, 2⅝, and 2¾ inches). The west shore as used in Table 1 includes the waters of the States of Illinois and Wisconsin south of Kewaunee. The east shore includes only the State of Michigan waters south of Frankfort. Upper Lake Michigan comprises the area north of a line extending from Kewaunee, Wisconsin, to Frankfort, Michigan.

The data are from specimens taken in 263 lifts of 738 gangs of nets at 141 stations (Figure 1) in the open lake and Green Bay. (When fish were scarce two or more gangs, as defined above, were set in one string of nets.) No *reighardi* were taken in 28 lifts at 12 stations (18

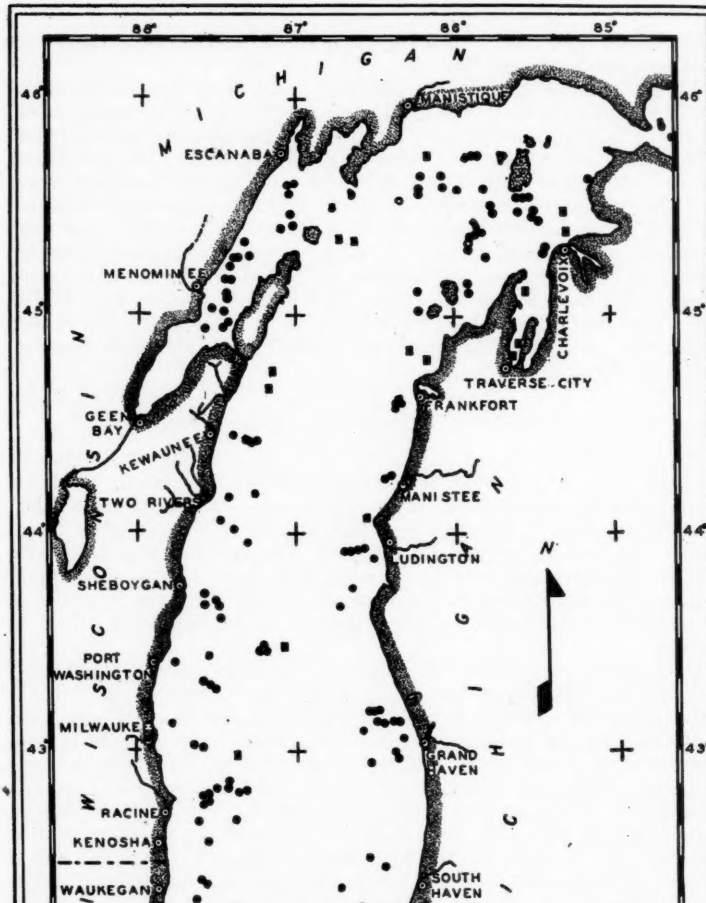

Figure 1.—Chart of Lake Michigan. Solid circles = stations at which *L. reighardi* were taken, 1930-1932; open circles = stations at which scale samples were obtained; squares = additional localities from which Koelz (1929) reported *L. reighhardi*

of these lifts and 10 stations were in Green Bay). The two stations in the open lake where no *reighardi* were taken were fished with only one set of nets each in November 1930, and were in depths of 16-17 fathoms (off Waukegan, Illinois) and 36 fathoms (off Kenosha, Wisconsin). The remaining lifts that produced no *reighardi* were at stations where the species occurred on other dates.

The data obtained in Green Bay during late September and early October 1930, are not shown in Table 1 because the gangs of nets used then included only the $2\frac{3}{8}$-, $2\frac{1}{2}$-, and $2\frac{5}{8}$-inch-mesh nets, and are not comparable with the gangs used at any other time or place. Although Reighard's chub was present in Green Bay during the late summer of 1930, it was scarce and was taken only occasionally. The 41 gangs set in 10-16 fathoms during September averaged only 0.1 *reighardi* per gang of three nets, and the 14 gangs set at the same depths in October averaged only 2.1 fish per gang. The six gangs set in 18-22 fathoms (20-29 fathom interval) in October took no *reighardi*.

The data in Table 1 from the lower part of Lake Michigan show that, in general, the number of Reighard's chub per gang of nets increased with each 10-fathom increase in depth up to 40 fathoms, and then decreased as the depth increased. With but one exception, *reighardi* were scarce or absent at depths of 70 fathoms and more. The data from Upper Lake Michigan show the same general trend in change of abundance with depth but suggest that the greatest concentration occurs at depths of 40-49 fathoms.

It is apparent that Reighard's chub was taken in greater numbers from a wider range of depth early in the season than during the summer, and that still later in the year there was a slight tendency for the species again to go to the deeper waters. Along the east shore *reighardi* seemed to be concentrated in depths of 30-79 fathoms in May, 20-69 fathoms in June, 20-59 fathoms in July, 20-39 (perhaps to 49) fathoms in August, 20-49 fathoms in September, and 30-59 fathoms in October. Along the west shore the depths with the greatest concentrations were 20-69 fathoms in May and June, 20-59 fathoms in July, 20-49 fathoms in August, 30-39 fathoms in September, and 30-49 fathoms in October and November. The depth ranges in which *reighardi* apparently concentrated in Upper Lake Michigan were 30-59 fathoms in June and July and 40-59 fathoms in August and September. In Green Bay the species was very scarce in April and increased progressively in numbers in May and June in depths of 16 to 19 fathoms.

Although nets were not set in all depth intervals each month, and virtually no lifts were made in less than 20 fathoms of water, except in Green Bay, it seems probable nevertheless, that Reighard's chub occurred most abundantly, except during the spawning season (May and June), between the depths of 20 and 60 fathoms in the open lake. The depths of concentration during the spawning season ranged from 20 to 79 fathoms in the lower part of the lake, from 30 to 59

Table 1.—The average number of Reighard's chub, Leucichthys reighardi, *per gang of nets taken each month in each 10-fathom interval of depth of water from the three sections of Lake Michigan, and Green Bay. The averages in the upper part of the table are based on the catches from gangs that contained one net each with meshes of 2⅜, 2½, 2⅝, 2¾, and 3 inches, but those in the lower part of the table are based on the catches from gangs that contained only one net each with meshes of 2½, 2⅝, and 2¾ inches. The number of gangs lifted are given in parentheses*

Month and year		Section of lake	Depth fished, in fathoms	Depth interval in fathoms								
				10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
May	1931	East shore	28-80	....	....	670.3(6)	273.0(1)	224.0(2)	....	196.0(4)	....	....
		West shore	27-66	....	70.5(2)	104.0(4)	61.5(2)	51.0(4)	89.5(2)	....	....	....
June	1931	East shore	28-75	....	94.0(1)	233.0(5)	44.7(3)	69.0(2)	46.0(3)	....	....	....
		West shore	27-73	....	36.5(4)	72.2(4)	23.9(11)	32.2(4)	21.7(7)	....	....	....
July	1930	East shore	25-56	....	189.0(2)	....	....	38.5(2)	....	....	....	....
		West shore	25-80	....	28.0(1)	69.0(1)	22.0(1)	....	5.5(2)	3.0(1)	....	....
	1931	East shore	23-75	....	117.8(4)	....	143.7(4)	96.8(4)	15.0(2)	....	....	....
		West shore	28-73	....	....	31.0(6)	11.5(2)	12.2(4)	3.0(3)	....	....	....
August	1930	East shore	25-78	....	128.5(4)	146.0(1)	....	9.5(2)	21.7(3)	....	....	....
		West shore	25-80	....	24.0(1)	13.3(3)	25.0(1)	....	3.0(4)	0.0(1)	....	....
	1931	East shore	23-74	....	164.2(4)	....	....	39.5(2)	18.8(4)	....	....	....
		West shore	30-87	....	....	49.7(12)	9.2(4)	5.0(2)	....	0.3(10)	0.3(6)	....
September	1931	East shore	27-92	....	99.0(1)	183.0(3)	77.0(1)	14.0(3)	41.0(3)	5.0(1)	....	....
		West shore	32-87	....	....	47.7(6)	....	8.2(4)	....	1.7(3)	1.0(2)	....
October	1930	East shore	33-45	....	....	32.3(3)	11.0(2)	....	....	....	....	....
		East shore	29-90	....	....	515.0(1)	....	230.0(1)	68.0(1)	8.0(1)	....	....
	1931	West shore	32-97	....	....	35.9(9)	49.7(6)	11.0(2)	....	1.8(4)	0.0(2)	2.0(2)
November	1930	West shore	16-43	0.0(1)	....	1.0(1)	15.5(2)	....	....	....	....	....
	1931	West shore	36-75	....	....	23.1(8)	70.0(3)	....	....	3.8(6)	....	....
April	1932	Green Bay	16-18	0.6(5)	....	....	....	....	....	....	....	....
May	1932	Green Bay	17-19	3.6(76)	....	....	....	....	....	....	....	....
June	1931	East shore	28-75	....	17.0(1)	69.4(5)	11.7(3)	26.0(2)	22.7(3)	....	....	....
		West shore	27-73	....	11.2(4)	14.8(4)	6.3(11)	13.2(4)	5.0(7)	....	....	....
	1932	Upper L. Michigan	23-65	....	....	17.8(6)	30.2(22)	13.7(7)	0.0(1)	....	....	....
		Green Bay	16-24	15.4(7)	11.6(14)	....	....	....	....	....	....	....
July	1930	East shore	25-56	....	56.0(2)	....	....	14.0(2)	....	....	....	....
		West shore	25-80	....	2.0(1)	18.0(1)	3.0(1)	....	1.5(2)	0.0(1)	....	....
	1931	East shore	23-75	....	47.5(4)	....	53.2(4)	38.5(4)	5.0(2)	....	....	....
		West shore	28-73	....	....	7.8(6)	4.5(2)	3.8(4)	1.0(3)	....	....	....
	1932	Upper L. Michigan	20-69	....	0.3(6)	13.8(9)	9.7(18)	15.8(80)	5.0(13)	....	....	....
August	1930	East shore	25-78	....	54.8(4)	63.0(1)	....	4.5(2)	7.7(3)	....	....	....
		West shore	25-80	....	4.0(1)	1.7(3)	5.0(1)	....	0.0(4)	0.0(1)	....	....
	1931	East shore	23-74	....	66.5(4)	....	....	18.5(2)	4.5(4)	....	....	....
		West shore	30-87	....	....	13.9(12)	2.2(4)	0.5(2)	....	0.1(10)	0.0(6)	....
	1932	Upper L. Michigan	17-73	....	6.3(7)	8.3(35)	28.6(28)	17.4(34)	9.0(5)	....	....	....
September	1931	East shore	27-92	....	30.0(1)	88.3(3)	25.0(1)	5.7(3)	15.3(3)	2.0(1)	....	....
		West shore	32-87	....	....	15.2(6)	....	3.2(4)	....	0.3(3)	0.0(2)	....
	1932	Upper L. Michigan	39-65	....	....	....	36.6(22)	15.0(26)	....	....	....	....

fathoms in the upper part, and in less than 25 fathoms in Green Bay. The extreme depth range from which *reighardi* were taken was 12-97 fathoms. The only depth fished without taking Reighard's chub was 10 fathoms (one lift in Green Bay on September 26, 1930).

The conclusions from this study agree in general with those of Koelz. Both studies place the lower limit of common occurrence of Reighard's chub, when not spawning, at 60 fathoms. The present data, however, place the upper limit of concentration at 20 instead of 30 fathoms. This study shows that *reighardi* ranges at least 7 fathoms deeper than found by Koelz, but he took it in water 6 fathoms shallower.

An examination of the temperatures obtained just off the bottom where the nets were set failed to show any close relationship between temperature and depth of greatest abundance of *reighardi*. The temperature in the depths where Reighard's chub was concentrated ranged from 3.8 to 4.8° C. (38.8 to 40.6° F.). The extreme temperatures recorded where *reighardi* were taken were 1.5 and 10.2° C. (34.7 and 50.4° F.).

The factors that caused the observed changes in depth of maximum abundance are not known definitely. It is possible that the abundance over such a wide range of depths in May and June was the result of extensive schooling, particularly by the fish already in the deeper waters (60-79 fathoms), preparatory to spawning. The changes in depth distribution later in the year may have been associated with feeding habits or with other unknown factors.

The data in Table 1 also afford an opportunity to compare the relative abundance of Reighard's chub in the waters of the three sections of the lake. The abundance was estimated from the average number of fish per comparable gang of nets fished in the same depths of water at the same time in the different sections. For example: in May 1931, the sum of the average number per gang along the east shore in depths of 30-59 fathoms was 1,167.3 and along the west shore it was 216.5 for those same depths (Table 1). The ratio of fish on the east shore to those on the west shore was 1,167.3/216.5 = 5.39. The sums of the average catch in the five depth intervals (20-69 fathoms) in June 1931 were 486.7 on the east shore and 186.5 on the west shore. The ratio for June was 486.7/186.5 = 2.61. The process was repeated for each month of each year. The average of the ratios represents an estimate of the relative abundance of Reighard's chub on the two sides of the lake. Unweighted sums and averages were used to reduce the effects of unequal fishing effort in the different sections.

It is estimated that Reighard's chub was approximately seven times (7.14) as abundant in 1930 and 1931 along the east shore of Lake Michigan as along the west shore. Similar estimates show that *reighardi* was three times (3.04) as abundant along the east shore in 1930 and 1931 as in Upper Lake Michigan in 1932, and that it was three

times (3.06) as abundant in the upper lake as along the west shore in those years.

The estimates of relative abundance of Reighard's chub on the east and west shores of the lower lake were based on the catches of nets that had fished an average of 11.5 and 11.7 days, respectively. The more restricted data of the east and west shores used for comparing the relative abundance in Upper Lake Michigan were from catches in nets that had fished an average of 6.2 days in the upper lake, 10.8 days on the east shore, and 11.7 days on the west shore.

It is apparent that the length of time between lifts in 1930 and 1931 could have had very little, if any, effect on the estimates of relative abundance on the two shores of the lower lake. Data published by Van Oosten (1935), and unpublished data on file in the Great Lakes laboratory of the U. S. Fish and Wildlife Service, suggest that the catch in Upper Lake Michigan would have been increased by at least 25 per cent had the nets fished 11 or 12 days instead of 6. If adjustments are made to allow for a 25 per cent increase in the catch in the upper lake, the estimated relative abundance on the east shore would be about 2¼ times that in the upper lake, and in the upper lake about 3¾ times greater than that on the west shore. The adjusted estimates represent, at best, a probable improvement over those obtained without regard for fishing time, and can not be taken to represent the true relative abundance of Reighard's chub in the different sections of Lake Michigan.

The influence of ecological factors, other than temperature, which apparently had no effect, on the relative abundance of Reighard's chub in the three sections of the lake can not be determined because of the lack of data. It is possible that natural factors were largely responsible for the greater abundance of the species along the east shore than in the upper lake since the commercial fishing intensity in the lower lake probably was greater for a longer period of time than it was farther north. In addition to the possible effects of ecological conditions, two other factors may have had considerable influence. The chub population along the west shore had been subjected for many years to a more intensive fishery with smaller-meshed nets than had the population on the east shore. The scarcity of Reighard's chub in depths of 70 and more fathoms (Table 1) strongly suggests that there is little if any intermingling of the populations from the two sides of the lake. The greater exploitation with smaller meshes on the west shore and the failure of that stock to be replenished appreciably from the more abundant stock on the east shore must be considered as important factors in explaining the relatively low level of abundance along the west shore of Lake Michigan.

Age Composition, Length Frequencies, and Maximum Size

The length-frequency distributions of the age groups are shown in Table 2. The differences in length distribution of fish whose ages

were determined from nets with different sizes of mesh were not large enough to require separate presentation. The number of specimens in each age group and the percentage of each group in the total sample of fish whose ages were determined are given at the bottom. The youngest individuals were in their third year of life and the oldest in the eighth. Age-group IV made up 50.2 per cent of the total sample. The three most abundantly represented age groups (III, IV, and V) made up 90.1 per cent of the total. Age-group VII was represented by only one individual and age-group II contained less than the number in age-group VI.

Table 2.—Length-frequency distribution of Reighard's chub, Leucichthys reighardi, *in Lake Michigan according to age. At the extreme right, the length-frequency distribution of all fish that were measured*

Standard length interval in millimeters	Age group							All fish
	II	III	IV	V	VI	VII	II-VII	
165-169	..	..	..	..	..	..	..	2
170-174	..	..	..	..	..	..	..	2
175-179	..	..	..	..	..	..	..	3
180-184	..	..	..	..	..	..	..	6
185-189	..	..	..	..	..	..	..	9
190-194	..	..	..	..	..	..	..	19
195-199	..	..	..	..	..	..	..	39
200-204	..	1	2	..	..	..	3	103
205-209	..	..	2	..	..	..	2	201
210-214	3	1	4	..	..	..	8	449
215-219	..	2	1	2	..	..	5	620
220-224	1	7	18	4	1	..	31	960
225-229	7	16	22	3	1	..	49	1,029
230-234	2	14	41	14	2	1	74	1,081
235-239	1	12	33	9	1	..	56	936
240-244	..	3	20	12	1	..	36	815
245-249	..	2	12	7	6	..	27	533
250-254	..	2	7	13	2	..	24	393
255-259	..	1	3	3	2	..	9	198
260-264	..	..	1	4	2	..	7	98
265-269	..	..	..	..	..	..	..	35
270-274	..	..	..	..	..	..	..	20
275-179	..	..	..	..	..	..	..	13
280-284	..	..	..	..	..	..	..	2
285-289	..	..	..	..	..	..	..	1
290-294	..	..	..	..	..	..	..	1
295-299	..	..	..	..	..	..	..	2
300-304	..	..	..	..	..	..	..	..
305-309	..	..	..	..	..	..	..	..
310-314	..	..	..	..	..	..	..	1
Total number........	14	61	166	71	18	1	331	7,571
Percentage in samples	4.2	18.4	50.2	21.5	5.4	0.3	100.0	..

All of the fish whose ages were determined had standard lengths of from 200 to 264 millimeters (9.4 to 12.2 inches, total length), with the mode (22.4 per cent) at 232 millimeters (10.8 inches, total length). The length-frequency distribution of all individuals that were measured is shown at the extreme right of Table 2. The modal frequency of all fish measured was the same as for the specimens whose ages were determined. The individuals whose ages were determined covered a length range that included 98.0 per cent of all of the measured fish.

The length distributions of the age groups overlapped to an unusual degree. The length range of the IV-group fish was large enough to include the ranges of all other groups. Fish within a 5-millimeter length interval were distributed among as many as six age groups (230-234), and a distribution over four and five age groups was very common. Because of the extreme overlap, the length at the modal frequency did not increase progressively as the fish became older. The modes were the same in age-groups II and III and in age-groups IV and V. It is possible that greater selection by the gill nets of II-group fish caused the length at modal frequency of that age group to be abnormally large.

The smallest *reighardi* was a mature male taken August 3, 1932, off Beaver Island, Michigan. It measured 165 millimeters, standard length (7.8 inches, total length), and weighed 1.75 ounces (50 grams). The longest and heaviest individual was a mature female taken off Escanaba, Michigan, May 13, 1932. It measured 314 millimeters, standard length (14.6 inches, total length), and weighed 15.7 ounces (445 grams). The longest male (284 millimeters, standard length; 13.2 inches, total length) was taken off Manistique, Michigan, on July 6, 1932. The heaviest male, which weighed 11.0 ounces (312 grams), was taken off Escanaba, Michigan, on May 21, 1932. It measured 277 millimeters, standard length (12.9 inches, total length). The oldest male was in its sixth year of life and the oldest fish (a female) was in its eight year.

Growth in Length and Weight

The data on length and weight at capture and the calculated length in millimeters at the end of each year of life are presented in Table 3 for the localities and sexes combined. Differences in growth of the fish in the two localities and of the sexes were unimportant. The data on length and weight at capture are the averages of fish taken during June and August and do not represent the size attained at the end of a year of life.

The average calculated lengths at the end of each year of life became progressively smaller as the age of the fish upon which calculations were based increased, but the discrepancies differ from the well-known "Lee's phenomenon" in that the first-year lengths were affected less than those for the second to fourth years. Although the material does not permit a detailed analysis of these discrepancies, it seems probable that selection by the size of mesh in the nets was an important factor.

The grand average calculated lengths and the annual increments in length are given at the bottom of Table 3, and are plotted in Figure 2. Growth was very rapid during the first year, followed by a progressive decrease in each succeeding year of life. If the average length attained at the end of the sixth year (237 millimeters) is taken as 100 per cent, it may be computed that 55 per cent of the total growth

Table 3.—Average length and weight at capture of Reighard's chub, Leucichthys reighardi, *collected in Upper Lake Michigan in 1932, and average calculated length attained by the age groups at the end of each year of life. Sexes combined*

Age group	Number of fish	Weight in ounces[1]	Total length in inches[1]	Standard length in millimeters[1]	Calculated standard length at end of year of life						
					1	2	3	4	5	6	7
II	14	5.7	10.4	224	141	196	....	....	....	....	....
III	61	6.1	10.7	231	133	178	213	....	....	....	....
IV	166	6.1	10.9	234	131	170	200	221	....	....	....
V	71	6.6	11.2	241	127	164	196	216	230	....	....
VI	18	7.1	11.4	245	118	156	181	203	222	238	....
VII	1	5.5	10.9	234	101	123	142	171	198	212	228
Grand average calculated length					130	170	200	218	228	237	228
Annual increment in length					130	40	30	18	10	9	-9
Number of fish					331	331	317	256	90	19	1

[1]The lengths and weights at capture are the averages of fish taken on different dates during the growing season and do not represent completed years of growth.

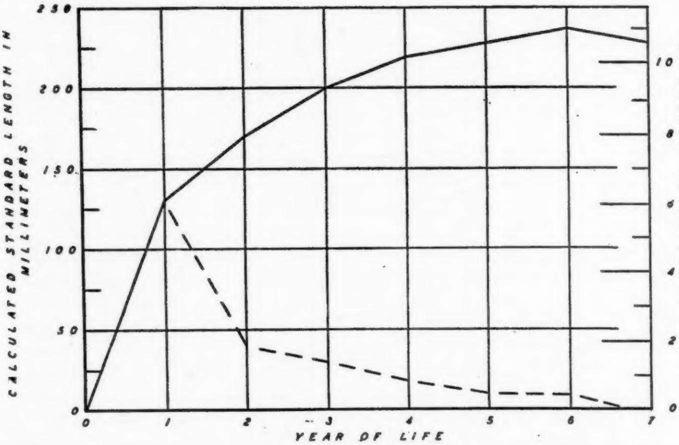

Figure 2.—Calculated growth in length (solid line), and increments of growth in length (broken line) of Reighard's chub, *Leucichthys reighardi*, in Lake Michigan. The sexes are combined.

in length was reached at the end of the first year, 72 per cent at the end of the second, 84 per cent at the end of the third, 92 per cent at the end of the fourth, and 96 per cent at the end of the fifth year of life.

Estimates of the percentage of total growth in weight completed each year may be obtained best from the calculated weights because the average weights of the age groups at capture do not represent complete years of growth. Weights computed to be equivalent to the average calculated standard length at the end of the first six years of life are: 41, 79, 118, 146, 163, and 179 grams, respectively. (See section on length-weight relationship for the equation used in the computations.) The weight increased at a nearly uniform rate for the first three years (41, 38, 39 grams), and then decreased progressively in each of the next three years (28, 17, 16 grams), (Figure 3). If the computed weight of 179 grams is taken as 100 per cent, it may be determined that 23 per cent of the total weight was reached at the end of the first year, 44 per cent at the end of the second, 66 per cent at the end of the third, 82 per cent at the end of the fourth, and 91 per cent at the end of the fifth year of life.

From these data it appears that the most rapid growth of *reighardi* in both length and weight occurs in the earlier years. However, the percentages of total length and weight attained at the end of each year of life do not necessarily represent the typical growth of the

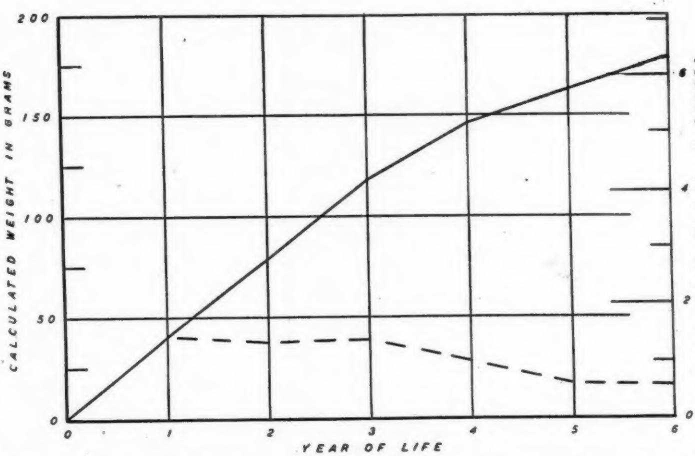

Figure 3.—Calculated growth in weight (solid line), and increments of growth in weight (broken line) of Reighard's chub, *Leucichthys reighardi*, in Lake Michigan. The sexes are combined.

species. The samples from which these data were obtained were taken by gill nets from a population that undoubtedly had been subjected to an intense gill-net fishery for many years. It is generally accepted that gill nets tend to remove the faster growing individuals of an age group first with the consequence that as the age increases the group is represented by fish that had grown more slowly in both length and weight. Average growth computed for the early years of life from a number of age groups probably closely approximates the true growth because fish with both large and small annual increments are included. As the age increases, it is to be expected that the calculated size at the end of each year would be less than the normal because of the earlier destruction by the fishery of the faster growing individuals. In spite of the fact that these data probably differ, particularly in the later years of life, from the course of growth of an undisturbed population, it may be that they describe rather accurately the growth histories of the fish taken by the commercial fishermen.

Growth Compensation

Growth compensation, or the tendency for the smaller yearlings to grow more rapidly in later years than the larger first-year fish, has been demonstrated for many species. The only information on compensation in growth in any of the species of chubs is that of Van

Table 4.—Growth compensation in age-group IV of Lake Michigan Reighard's chub, Leucichthys reighardi, *as demonstrated by the computed average standard lengths and average increments of length for each year of life of three first-year size groups. Sexes combined*

Interval of first-year growth in millimeters	Number of fish	Average computed standard length in millimeters for year				Average standard length at capture	Average computed increment of length in year				
		1	2	3	4		1	2	3	4	5[1]
Less than 125	58	110	156	193	216	232	110	46	37	23	16
125-140	54	132	172	200	220	232	132	40	28	20	12
More than 140	54	151	184	209	227	237	151	33	25	18	10
Maximum differences		41	28	16	11	5	....	....	....	....	....

[1]An uncompleted year.

Oosten (1937) who found that the smaller yearlings of the Lake Superior longjaw (*Leucichthys zenithicus*) grew more rapidly in later years than did the fish with greater first-year growth.

The average computed standard lengths and the average annual increments in length are shown in Table 4 for three yearling size groups of age-group IV of the Lake Michigan *reighardi*. The larger yearlings continued to be the longer fish in all years of life, but the difference in size between the largest and smallest groups decreased progressively each year from 41 millimeters at the end of the first year to 11 millimeters at the end of the fourth. It may be seen from the average annual increments in length that the smallest yearlings grew more rapidly than the larger yearlings in the second and later years of life. These data make it appear that the "law of growth compensation" holds for the Lake Michigan *reighardi*.

Length-weight Relationship and Coefficient of Condition

The data on the length-weight relationship of *reighardi* are shown in Table 5. Although certain differences existed in the relationship that perhaps were associated with sex, season, and locality of capture, a single curve based on all specimens is believed to express satisfactorily the changes in weight with changes in length. (See Table 8 and discussion for details of differences in relative heaviness.) The computed weights were obtained by use of the equation, $W = 24.711 \times 10^{-5} L^{2.468}$, where W = weight in grams and L = standard length in millimeters. That equation was fitted to the average lengths and weights of *reighardi* in each 5-millimeter interval of standard length over the range 190-279 millimeters. The empirical and computed weights never differed by more than 3 grams in any 5-millimeter length interval in the range to which the equation was fitted. The low value of the exponent in the equation (2.468) makes it evident that the weight increased at a rate much less than the cube of the length.

Figure 4, based on the data in Table 5, has been drawn to permit ready conversion of standard length in millimeters to total length in inches, and of grams to ounces. The solid circles represent the empirical data, and the curve represents the computed weights. The solid portion of the curve covers the length range to which the equation was fitted. The factors for converting lengths are given in Table 6.

The coefficient of condition, K, was computed from the averages of all individuals in each 5-millimeter standard length interval by means of the formula, $K = \frac{W \times 10^5}{L^3}$, where W = weight in grams and L = standard length in millimeters. Fluctuations in the value of K represent changes in the condition, or relative heaviness, of the fish. Poor condition is shown by low values and good condition by high ones.

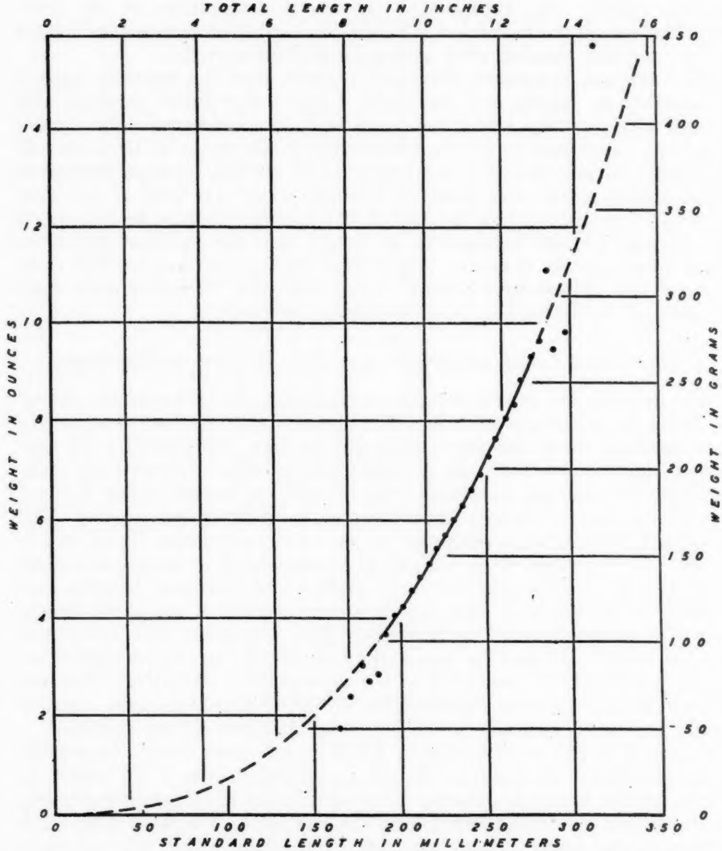

Figure 4.—The computed length-weight relationship of Reighard's chub, *Leucichthys reighardi*, in Lake Michigan. The sexes are combined. Solid circles = empirical data; solid portion of the curve = the standard length range to which the equation was fitted.

Table 5.—Length-weight relationship of Reighard's chub, Leucichthys reighardi, *in Lake Michigan, 1930-1932. The data of both sexes from all localities are combined. The computed weights were obtained from the equation,* $W = 24.711 \times 10^{-5} L^{2.468}$

Standard length interval in millimeters	Total length in inches equivalent to mid-point	Empirical weight in		Computed weight in grams	*K*	Number of fish
		Ounces	Grams			
165-169	7.9	1.8	50	73	1.11	1
170-174	8.1	2.4	68	80	1.36	1
175-179	8.3	3.0	86	88	1.52	2
180-184	8.6	2.7	77	93	1.28	4
185-189	8.8	2.9	81	100	1.24	5
190-194	9.0	3.7	104	107	1.47	9
195-199	9.3	4.0	115	114	1.50	31
200-204	9.5	4.2	120	121	1.46	74
205-209	9.7	4.6	129	128	1.45	149
210-214	9.9	4.8	137	136	1.44	307
215-219	10.1	5.1	145	144	1.42	417
220-224	10.3	5.4	154	152	1.41	675
225-229	10.6	5.7	162	161	1.38	731
230-234	10.8	6.0	171	170	1.37	810
235-239	11.0	6.3	179	179	1.34	690
240-244	11.3	6.6	188	189	1.33	672
245-249	11.5	7.0	197	198	1.31	433
250-254	11.7	7.3	207	208	1.29	336
255-259	11.9	7.6	217	217	1.29	163
260-264	12.2	8.1	229	229	1.27	92
265-269	12.4	8.4	237	240	1.25	29
270-274	12.6	8.8	251	249	1.26	19
275-279	12.9	9.4	265	263	1.35	13
280-284	13.1	9.6	274	275	1.21	3
285-289	13.3	11.1	315	285	1.35	1
290-294	13.5	9.5	269	295	1.10	1
295-299	13.8	9.8	279	313	1.06	2
300-304	14.0	....	....	326	....	....
305-309	14.2	....	....	339	....	....
310-314	14.5	15.7	445	359	1.44	1

Table 6.—Factors for converting standard to total length, and vice versa, with and without change of unit of measurement, for Reighard's chub, Leucichthys reighardi, *of Lake Michigan*

Standard length interval	Number of fish	S.L. to T.L.[1]	T.L. to S.L.	S. L. (millimeters) to T.L. (inches)	T.L. (inches) to S.L. (millimeters)
160-209	384	1.196	0.836	0.0471	21.234
210-249	6,423	1.182	0.846	0.0465	21.488
250-319	764	1.178	0.849	0.0464	21.565

[1]T.L. = total length; S.L. = standard length.

The values of *K* as determined for each length interval varied irregularly for lengths of less than 195 millimeters, but showed a definite tendency to decrease with each 5-millimeter increase in length from 195 to 299 millimeters. The one fish in the 310-314 millimeter interval was exceptionally heavy for a fish of that length.

When the data for fish taken in nets with meshes of 2½, 2⅝, and 2¾ inches (the sizes used when the scale samples were obtained) were examined separately, they revealed the same tendency for the values of *K* to decrease with increased length in each net as did the values in Table 5. The values for fish of the same length were practically

the same in the $2\frac{1}{2}$- and $2\frac{5}{8}$-inch meshes, but were somewhat greater in the $2\frac{3}{4}$-inch mesh. Since the nets with meshes of $2\frac{3}{4}$ inches and larger took relatively few fish, their effect on the values of K in the combined data would be small. Because of the apparent selection by the nets, both the length-weight equation and the values of K must be considered as describing only the present data, and can not be taken as descriptive of truly unselected samples of Reighard's chub.

The values of K according to age and to length within the age groups are given in Table 7. Since preliminary analysis showed the same trends in the changes of the data when separated by locality, sex, and stage of maturity of the fish, the table presents the combined data. It may be seen that there was a tendency for the values of K to decrease with increased length of fish within each well represented age group. The data suggest that good condition was associated with slow growth. However, the change in condition as the length of fish increased may have been the result of selection by the gill nets which tend to take the heavier of the shorter fish and the lighter of the longer individuals. The values of K for fish of the same length but of different age show that there was a somewhat indefinite tendency

Table 7.—Coefficient of condition according to age and length of Reighard's chub, Leucichthys reighardi, *in Lake Michigan. Sexes combined. Number of specimens in parentheses*

Standard length in millimeters	Age group						
	II	III	IV	V	VI	VII	II-VII
200-204	....	1.69(1)	1.37(2)	....	....	....	1.47(3)
205-209	....	....	1.58(2)	....	....	....	1.58(2)
210-214	1.46(3)	1.52(1)	1.50(4)	....	....	....	1.49(8)
215-219	....	1.49(2)	1.14(1)	1.53(2)	....	....	1.44(5)
220-224	1.40(1)	1.41(7)	1.43(18)	1.36(4)	1.28(1)	....	1.40(31)
225-229	1.41(7)	1.42(16)	1.44(22)	1.35(3)	1.61(1)	....	1.42(49)
230-234	1.39(2)	1.39(14)	1.35(41)	1.40(14)	1.39(2)	1.22(1)	1.36(74)
235-239	1.49(1)	1.34(12)	1.38(33)	1.37(9)	1.58(1)	....	1.38(56)
240-244	....	1.36(3)	1.32(20)	1.35(12)	1.23(1)	....	1.33(36)
245-249	....	1.38(2)	1.29(12)	1.32(7)	1.37(6)	....	1.34(27)
250-254	....	1.29(2)	1.29(7)	1.30(13)	1.36(2)	....	1.30(24)
255-259	....	1.48(1)	1.27(3)	1.27(3)	1.18(2)	....	1.28(9)
260-264	....	....	1.16(1)	1.23(4)	1.31(2)	....	1.24(7)
Average	1.42(14)	1.40(61)	1.37(166)	1.35(71)	1.36(18)	1.22(1)	1.37(331)

for the values to decrease with increased age and seem to suggest that good condition was associated with rapid growth. The data, therefore, conflict. The values of K with all age groups combined exhibited a definite tendency to decrease with increasing length that is very similar to that shown by the K values for all fish in Table 5. Because of the contradictory evidence, the most valid conclusion appears to be that the data demonstrate no definite relationship between condition and rate of growth.

The average coefficients of condition of fish taken in each month of each year are presented in Table 8. The stages of sexual maturity of the males taken in the same month had so little effect on the values

Table 8.—Coefficient of condition of Reighard's chub, Leucichthys reighardi, *in Lake Michigan according to sex and date of capture. Number of specimens in parentheses*

Sex	Year	Average K in month							Average
		May	June	July	August	September	October	November	
Male, all	1930	....	....	....	1.37(131)	....	....	1.37(10)	1.37(141)
	1931	1.38(695)	1.34(86)	1.34(16)	1.44(128)	1.43(61)	1.44(24)	1.46(6)	1.39(1,016)
	1932	1.28(138)	1.27(128)	1.33(55)	1.35(113)	1.40(35)	....	....	1.31(469)
Female, mature and ripe	1930	....	....	....	1.44(65)	1.43(2)	....	1.46(28)	1.45(95)
	1931	1.48(349)	1.46(51)	1.43(36)	1.43(208)	1.46(118)	1.48(72)	1.53(6)	1.46(840)
	1932	1.35(151)	1.31(290)	1.36(395)	1.36(755)	1.45(302)	....	....	1.37(1,893)
Female, spent	1930	....	....	....	1.38(270)	....	....	....	1.38(270)
	1931	1.34(263)	1.34(90)	....	1.29(4)	....	....	....	1.34(357)
	1932	1.39(4)	1.20(275)	1.26(241)	1.29(67)	1.37(2)	....	....	1.24(589)
Female, all	1930	....	....	....	1.39(335)	1.43(2)	....	1.46(28)	1.40(365)
	1931	1.42(612)	1.38(141)	1.43(36)	1.43(212)	1.46(118)	1.48(72)	1.53(6)	1.43(1,197)
	1932	1.35(155)	1.26(565)	[1]1.31(637)	1.36(822)	1.45(304)	....	....	[1]1.33(2.483)
Male and female	1930	....	....	....	1.38(466)	1.43(2)	....	1.44(38)	1.38(506)
	1931	1.40(1,307)	1.37(227)	1.40(52)	1.43(340)	1.45(179)	1.47(96)	1.49(12)	1.41(2.213)
	1932	1.32(293)	1.26(693)	1.32(692)	1.35(935)	1.44(339)	....	....	1.33(2,952)

[1]Includes 1 immature female.

of *K* that the data are not shown separately. Likewise, the mature and ripe females captured in the same month had values of *K* that were so similar that they were combined. Only the data for the spent females need be given separately.

The monthly values of *K* were higher for all fish in 1931 than in 1930 and 1932, except for the mature females of August 1930, and the spent females of May 1932, and of August 1930. Only few 1930 data are available for comparisons, but these indicate that the *K* values of this year were higher than those of 1932. The differences in the relative heaviness of the fish taken in 1931 and 1932 tended to decrease as th season advanced. The discrepancies were comparatively large in May, usually somewhat greater in June, and then decreased until the values of *K* were practically the same in September, when no further comparisons were available. The poorer condition characteristic of the fish taken from northern Lake Michigan in 1932 may have been due to differences in ecological conditions, or perhaps those fish represent a distinct race as suggested by Koelz.

The seasonal changes in relative heaviness followed the same general trend irrespective of the sex and stage of maturity of the fish. In general the values of *K* were higher in May than in June, and thereafter tended to increase each month until November. The fish of both sexes taken in November were relatively heavier than those taken in May, which suggests some loss of weight during the winter. Usually the difference in the values of *K* for fish of the same sex and stage of maturity was not large in successive months (difference of 0.05 or less in 36 of 48 comparisons).

The reasons for the general trend in changes in the values of *K* through the season are not known definitely. Food supply, activity, and other unknown factors may have been involved.

The males were relatively lighter than the mature and ripe females in every month of all three years with the single exception of August 1931. The *K* values tended to come together as the season advanced. The spent females usually were lighter than the males in each month, and were always relatively lighter than the mature and ripe females except in May 1932 when only four spent females were available for comparison.

The distinctly lower values of *K* for the spent females made it seem desirable to determine more precisely the percentage of weight lost by the females on spawning. The samples obtained May 7-23, 1931, and June 5-16, 1932, all dates inclusive, contained adequate numbers of gravid and spent females to be satisfactory for such a study. The weight in grams and *K* of both gravid and spent females, the loss of weight in grams, and the percentage loss are shown in Table 9. Both weighted[1] and unweighted averages of *K* and percentage loss are

[1]The percentage loss was weighted by multiplying the percentage loss of fish in each 5-millimeter interval of standard length by the product of the number of gravid and the number of spent fish in the interval.

Table 9.—Average weight and condition (K) *of gravid and spent females of Reighard's chub,* Leucichthys reighardi, *in Lake Michigan, the loss of weight at spawning, and the percentage loss*

Standard length interval (millimeters)	Gravid females			Spent females			Loss (grams)	Percentage loss
	Number of fish	Average weight (grams)	Average *K*	Number of fish	Average weight (grams)	Average *K*		
May 7 to 23, 1931								
205-209	14	132	1.47	16	119	1.32	13	9.8
210-214	15	141	1.48	23	133	1.38	8	5.7
215-219	33	153	1.48	31	139	1.36	14	9.2
220-224	38	161	1.47	33	150	1.35	11	6.8
225-229	60	176	1.50	33	162	1.38	14	8.0
230-234	40	183	1.47	36	167	1.34	16	8.7
235-239	42	194	1.46	21	177	1.33	17	8.8
240-244	34	210	1.48	21	187	1.32	23	11.0
245-249	22	217	1.44	15	199	1.32	18	8.3
Total	298	....	....	229	....	....	....	....
Unweighted average	....	....	1.47	....	....	1.34	....	8.5
Weighted average	....	....	1.48	....	....	1.35	....	8.4
June 5 to 16, 1932								
220-224	19	145	1.33	21	137	1.25	8	5.5
225-229	30	156	1.33	30	146	1.25	10	6.4
230-234	46	168	1.35	45	154	1.23	14	8.3
235-239	40	172	1.29	37	159	1.19	13	7.6
240-244	52	182	1.28	50	172	1.21	10	5.5
245-249	34	193	1.28	38	176	1.17	17	8.8
250-254	27	207	1.31	27	186	1.16	21	10.1
255-259	16	216	1.29	10	196	1.17	20	9.3
Total	264	....	....	258	....	....	....	....
Unweighted average	....	....	1.31	....	....	1.20	....	7.7
Weighted average	....	....	1.31	....	....	1.21	....	7.4

given. The females lost approximately 1 per cent more of their prespawning weight in 1931 than in 1932. Computed on the basis of the weighted and unweighted average percentages of loss for the two years combined, the females may be said to lose 8 per cent of their weight at spawning. A similar analysis of the data from gravid and spent males did not show any loss of weight on spawning.

Sex Ratio

The data on sex ratio of the *reighardi* whose ages were determined (Table 10) suggest that there was little change in the relative abundance of the sexes in age-groups II to V. The tendency appears to have been for the relative abundance of the females to decrease slightly with each increase in age from the third through the sixth year of life (age-groups II-V). However, only females occurred in age-groups VI and VII. The females were strongly dominant in all age groups and made up 85 per cent of the total sample of fish whose ages were determined. The complete disappearance of the males from the two older age groups of Reighard's chub in Lake Michigan may have been the result of the failure to take large numbers of fish belonging to either group (18 individuals in age-group VI and 1 in age-group VII). However, the presence of 1 male in 14 fish assigned to age-group II and the absence of males in the 18 assigned to age-group VI seems to suggest that the males were relatively less abundant in the older group. That suggestion is in agreement with the conclusion of Van Oosten (1937) that the males of the Lake Superior longjaw (*L. zenithicus*) disappeared more rapidly from the catch than the females as the age increased.

All of the available data on the sex ratio of Reighard's chub are presented in Table 11. It is to be seen that there was little change in the relative abundance of the sexes in the three months of 1930 for which there are data. The females dominated in the catch each month. The sexes were represented in approximately equal numbers in May and June 1931, but the females made up the greater part of the catch in all months later in the season except in November when only 12 fish were taken. The relative abundance of the sexes did not change a great deal during July, August, and September. Relatively more females were taken in October than in any other month of that year. The ratio of four females to each male in April 1932 can not be considered as reliable because of the few fish taken. The sexes occurred

Table 10.—Percentage of male and female Reighard's chub, Leucichthys reighardi, *of Lake Michigan in each age group. Number of specimens in parentheses*

Sex	Age g oup						
	II	III	IV	V	VI	VII	II-VII
Male, percentage......	7.1 (1)	13.1 (8)	16.3 (27)	18.3(13)	....	....	14.8 (49)
Female, percentage..	92.9(13)	86.9(53)	83.7(139)	81.7(58)	100.0(18)	100.0(1)	85.2(282)

Table 11.—Number of male and female Reighard's chub, **Leucichthys reighardi,** *in Lake Michigan, and the percentage of females according to month and year of capture*

Month	1930			1931			1932		
	Number of males	Number of females	Percentage of females	Number of males	Number of females	Percentage of females	Number of males	Number of females	Percentage of females
April	....	....	....	....	....	....	1	4	80.0
May	....	....	....	1,189	1,162	49.4	137	146	51.6
June	....	....	....	398	413	50.9	119	575	82.9
July	171	403	70.2	70	128	64.6	59	660	91.8
August	206	522	71.7	146	246	62.8	118	839	87.7
September	....	....	....	71	134	65.4	37	310	89.3
October	....	....	....	32	100	75.8	....	....	....
November	11	30	73.2	6	6	50.0	....	....	....
All months	388	955	71.1	1,912	2,189	53.4	471	2,534	84.3

in about equal numbers in May 1932, after which the females dominated strongly in the catch each month. It is apparent that the sexes of Reighard's chub were segregated for the greater part of the year covered by these data, and that usually the females dominated in the catches. There is some evidence that the sexes approach equality in numbers during part of the spawning season in May and June.

Comparisons of annual differences in the sex ratio in the catch from southern Lake Michigan in 1930 and 1931 must be limited to the months of July and August because of the absence or scarcity of data for the other months. The females were relatively more abundant in the catches of both months in 1930 than in 1931. The data obtained in 1932 were from northern Lake Michigan and therefore differ from those collected in 1930 and 1931 not only as to year but also as to the section of the lake and the sizes of mesh in the gangs of nets. In every month except May, the females were relatively much more abundant in 1932 than in either 1930 or 1931.

Detailed analysis of the data brought out the fact that as the size of mesh increased from 2⅜ to 2½ to 2⅝ inches there was usually an increase in the percentage of females in the catch. The increase in mesh size from 2½ to 2⅝ inches had little effect on the percentage of females taken in July, August, and September 1932. A further increase in mesh size to 2¾ inches brought about some increase in the percentage of females taken in 1930 and 1931 but had little effect in 1932. There were too few fish taken by the 3-inch meshes to permit valid comparisons with the catch taken in smaller meshes. The relative abundance of the sexes taken by each size of mesh in general followed the trends for all data as seen in Table 11.

It seems apparent that the unequal representation of the sexes resulted, at least in part, from selection by the nets. Since the males usually were more slender bodied than the females, it is probable that the nets allowed at least some of them to escape. Some other factor or factors (perhaps spawning) must have exerted a strong influence in May and June 1931 and May 1932 when the sexes occurred in approximately equal numbers.

Spawning

A fairly accurate idea of the spawning season of *reighardi* may be had from an examination of the data on the stages of sexual maturity at different dates during the seasons of 1931 and 1932. Nearly one-half of the males and almost all of the females were either gravid or spent on May 6, 1931, the first date that year on which the stages of sexual maturity were determined. High percentages of gravid and spent individuals of both sexes continued through June 13, 1931. The relative abundance of the gravid and spent fish shifted during that period from a majority of gravid early in the season to a predominance of spent fish on June 13. No data on the stages of sexual maturity

were obtained in 1931 between June 13 and July 2, at which time there were practically no gravid fish of either sex. No gravid or spent males were taken later than July 2 in the season of 1931, but an occasional gravid female was recorded as late as August 31, and one spent female was recorded on September 29.

In 1932, the first spent female was taken May 21, and the first spent male on May 28. Gravid individuals of both sexes were taken as early as May 13, but there is nothing in the catch records to indicate that any spawning occurred that early. It was not until June 10, 1932, that it could be said that any significant number of either sex had spawned. High percentages of gravid and spent fish of both sexes were taken from then on through June 16. No data on the stages of sexual maturity were obtained between June 16 and July 6, 1932, when there were practically no gravid fish of either sex, and only the females were present in large numbers as spent individuals. An occasional spent male was taken as late as July 20, and small numbers of both gravid and spent females were recorded as late as September 1.

The nets employed to catch the fish from which the above data were obtained were set in 27 to 79 fathoms of water in 1931 and in 23 to 65 fathoms in 1932. The fact that gravid individuals of both sexes were taken at all depths in the above ranges makes it appear that the fish were spawning or ready to spawn over a wide area. Also, the fact that the species occurred in larger numbers over a wider depth range during May and June than in any other months (Table 1) is another reason for assuming that spawning occurs over a wide range of depth. The temperature during May and June varied from 3.8 to 4.7° C. (38.8 to 40.5° F.).

Not only was there a wide range of depth of water from which gravid and spent individuals were taken but also a wide range in the type of bottom presumably used as spawning beds. Nets containing gravid and spent individuals were lifted from sand, silt, silt and clay, and clay bottoms.

A criterion used by Koelz to determine the spawning runs of the several chubs was a heavy run of which one species constituted a majority. Thus a lift made May 26, 1921, off Port Washington, Wisconsin, in 14 to 35 fathoms from a muddy sand bottom was considered to be from the spawning run of Reighard's chub. On the same basis, the present data reveal that spawning runs of Reighard's chub were encountered at the following ports: Sheboygan, Wisconsin, on May 6, 1931, in 55-65.5 fathoms; Racine, Wisconsin, on May 22, 1931, in 36.5-40 fathoms; St. Joseph, Michigan, on May 12 and 27, 1931, in 30-33 fathoms, and on May 27 in 47.5-48 fathoms; Grand Haven, Michigan, on May 28 and June 10, 1931, in 28.5-32 fathoms, and on May 28, 1931, in 50-56.5 fathoms; and Ludington, Michigan, on May 15, June 11 and 23, 1931, in 29.5-33.5 fathoms, and on May 19 and 29, 1931, in 75-80 fathoms.

It is believed that the presence of relatively high percentages of

gravid and spent fish in the same lifts indicated that the spawning grounds were not far distant even though the species did not constitute a majority in the catch. Consequently, the present data suggest that Reighard's chub probably spawns also off Manistique, Michigan, and to the east of Washington Island. The percentages of spent fish taken off Charlevoix, Michigan, in July 1931 suggest the probability that *reighardi* spawns in that area. Koelz presented evidence which leads one to believe that *reighardi* probably spawns also off the ports of Sturgeon Bay, Algoma, and Milwaukee, Wisconsin; Michigan City, Indiana; and Northport, Michigan.

It seems reasonable to conclude that *reighardi* spawns chiefly during May and June in water that may range from 20 to 79 fathoms, where the temperature varies from 3.8 to 4.7° C. (38.8 to 40.5° F.), and where the bottom may be sand, silt, or clay, and that the spawning areas are numerous and widely distributed in Lake Michigan. The season may perhaps begin earlier or extend later in different years depending on annual variations in the unknown controlling factors. A few individuals do not spawn until as late as September in some years. Koelz believed that *reighardi* probably spawned in May and June in 14 to 35 fathoms on a muddy bottom. The differences in the conclusions from the two studies appear to be the result of the more extensive data in the present study rather than to any fundamental differences in distribution during the spawning season.

Summary

1. The materials for this study were taken by means of small-mesh gill nets set on the bottom in Lake Michigan during the years, 1930-1932. The number of specimens employed in each phase of the study are: age and growth, 331 (all secured in northern Lake Michigan during 1932); length frequency distribution, 7,571; length-weight relationship, 5,671; and sex ratio, 8,449.

2. *Reighardi* occurred most abundantly, except during the spawning season, in water that was 20-60 fathoms deep, where the temperature was from 3.8 to 4.8° C. (38.8 to 40.6° F.). The extreme range in depth was 12 to 97 fathoms, and the extremes of temperature were 1.5 to 10.2° C. (34.7 to 50.4° F.).

3. Reighard's chub was seven times as abundant along the east shore as along the west shore of Lake Michigan. The abundance along the east shore was between two and three times that in the upper part of the lake, and in the upper lake between three and four times that along the west shore. The data indicate the existence of separate populations on the two shores of the lower lake. The greater exploitation with smaller meshes probably accounts for the relative scarcity of *reighardi* along the west shore.

4. The sexes grew at approximately the same rate in both length and weight.

5. The most rapid growth in length occurred during the first year of life, following which there was a progressive decrease in the annual increments in length.

6. The weights computed to be equivalent to the average calculated standard lengths at the end of each year of life show that the best growth in weight occurred during the first three years of life when the annual increments were about the same.

7. Age-group IV dominated in the samples of fish whose ages were determined, and made up 50.2 per cent of the total. Age-group V was represented by the next

largest number of fish, and age-group III was the third largest group. No fish were taken that were younger than age group II or older than age-group VII. The length distributions overlapped to an unusual degree.

8. The smallest individual taken was a mature male that measured 165 millimeters, standard length, and weighed 50 grams (7.8 inches, total length, and 1.75 ounces). The largest specimen was a mature female that measured 314 millimeters, standard length, and weighed 445 grams (14.6 inches, total length, and 15.7 ounces).

9. The law of growth compensation holds for the *reighardi* of Lake Michigan. The larger yearlings remained the larger fish into the fifth year of life, but the difference between the larger and smaller groups became less each year.

10. The length-weight relationship for all fish is expressd satisfactorily by the equation, $W = 24.711 \times 10^{-5} L^{2.468}$.

11. No relationship between condition (K) and rate of growth could be demonstrated.

12. Condition (K) was better in 1931 than in either 1930 or 1932, and usually better in 1930 than in 1932. In general the values of K decreased from May to June and then increased each month till the end of the season. The same general trends were observed for both sexes at all stages of maturity.

13. The stage of sexual maturity had no effect on the condition of the males. The mature and gravid females had approximately the same values of K, but the spent females were distinctly the more slender. The values of K for the males were less than for the mature and gravid females, but were greater than for the spent females.

14. The females lost 8 per cent of their weight on spawning. No loss of weight on spawning could be demonstrated for the males.

15. There was little change in the relative abundance of the sexes in age-groups II to V (81.7 to 92.9 per cent females). No males were assigned to age-groups VI and VII. The percentage of females in the entire sample of fish whose ages were determined was 85.2. The females were always strongly dominant in the samples except during May and June 1931 and May 1932 when the sexes occurred in about equal numbers.

16. Spawning occurs chiefly in May and June and may take place in depths of 20 to 79 fathoms at temperatures of 3.8 to 4.7° C. (38.8 to 40.5°F.) over sand, silt, silt and clay, or clay bottoms.

Literature Cited

Koelz, Walter

1929. Coregonid fishes of the Great Lakes. Bull. U. S. Bur. Fish., Vol. 43, Part 2, pp. 297-643.

Pritchard, Andrew L.

1931. Taxonomic and life history studies of the ciscoes of Lake Ontario. Univ. Toronto Studies. Pubs. Ont. Fish. Res. Lab., No. 41, 78 pp.

Van Oosten, John

1929. Life history of the lake herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. U. S. Bur. Fish., Vol. 44, pp. 265-428.

1935. Logically justified deductions concerning the Great Lakes fisheries exploded by scientific research. Trans. Am. Fish. Soc., Vol. 65, pp. 71-75.

1937. The age, growth, and sex ratio of the Lake Superior longjaw, *Leucichthys zenithicus* (Jordan and Evermann). Pap. Mich. Acad. Sci., Arts, Let., Vol. 22 (1936), pp. 691-711.

FOOD PROGRESSION IN YOUNG WHITE PERCH *MORONE AMERICANA* (GMELIN) FROM BANTAM LAKE, CONNECTICUT

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ABSTRACT

On August 26 and 27, 1941, collections of young white perch, *Morone americana* (Gmelin), were made at 8:30 and 11:30 p.m. and at 2:30 and 4:30 a.m. when the fish had moved over shoals. The stomach and intestinal contents of 50 specimens in each collection were examined; estimates were made of the fullness of the stomachs and of the volume of the various food organisms. The position of the food was diagramatically noted. The stomachs examined from the 8:30 p.m. collection held considerable food, but those from subsequent ones held increasingly less, until the 4:30 a.m. collection, when about 95 per cent of the fish examined had empty stomachs. The most important food organisms in the 8:30 p.m. collection were Cladocera, chironomid larvae, and a certain adult of the Hymenoptera. In the following collections, the volume of Cladocera gradually decreased in the digestive tract and such forms as *Hyalella*, ant adults, midge pupae, and mayfly nymphs increased greatly. In the several collections there was a marked tendency for the important food organisms to occupy a similar position in the digestive tract of all fish in the same collection. A well defined progression of the main food organisms could be followed through the digestive tract from the initial collection to the last.

INTRODUCTION

Collections of young white perch,[1] *Morone americana* (Gmelin), were made in the summer of 1940 at Bantam Lake, Litchfield County, Connecticut, during the course of certain life-history investigations being conducted by the Lake and Pond Survey of the State Board of Fisheries and Game. The distribution of white perch in Bantam Lake is such that both young and adults may be seined from shoal waters, less than 3 to 4 feet deep, only during the evening or night when there is a marked inshore movement. The extensive shoals over which collecting was carried out had a sandy bottom kept relatively free from rooted aquatic vegetation by wave action; *Vallisneria spiralis, Chara coronata,* and *Najas flexilis* were present only in sparse quantities.

In the examination of the stomach contents of the young white perch collected in 1940, it was noted that organisms of certain groups occurred with unusual regularity in certain positions in the stomach. This arrangement suggested a feeding pattern to which the majority

[1]Young in this paper refers to fish of the year, *i.e.*, age-group O.

of the feeding individuals in the collection had subscribed. Whether or not the position of the food was the result of selective feeding on the part of the young white perch or the result of a changing fauna coincident with moving from a deep-water to a shallow-water environment, is of no consequence at the moment. However, the results of this initial food study on young white perch suggested that the position of food organisms in the digestive tract might give pertinent information on both individual and collective feeding habits of the fish.

Materials and Methods

On August 26 and 27, 1941, a series of collections of white perch were made which would, it was felt, bring to light further evidence on feeding progression in these fish. Seining operations with two 20-foot seines operated by a crew of four men, were carried out at 2- to 3-hour intervals with the following results:

1. 7:00-7:45 p.m.[2]—No white perch over shoals near shore; a few (5) individuals taken by short, quick hauls in 3 to 4 feet of water about 150 feet from shore.
2. 8:30 p.m.—Large numbers of young white perch collected over entire shoal area.
3. 11:30 p.m.—As in 8:30 p.m. collection.
4. 2:30 a.m.—As in 8:30 p.m. collection.
5. 4:30 a.m.—As in 8:30 p.m. collection.
6. 6:00 a.m.—White perch absent from shoal area near shore.

From the above observations it is apparent that considerable numbers of white perch made their appearance in the shoals during a three-quarter hour interval at the approach of darkness, between the first and second seinings. By 6:00 a.m., when it had already become quite light, no white perch could be collected on the shoals. Collecting in areas seined in previous hours was very poor compared with untouched waters only 50 to 100 feet away. The movements of young yellow perch (*Perca flavescens*) taken at the same time, paralleled those of the white perch, except in the 6:00 a.m. collection when large numbers of the former species still frequented the shallows.

From previous experience it was known that specimens preserved directly in formalin were inclined to disgorge their stomach contents. Consequently the fish in each collection were allowed to suffocate before being preserved in 10 per cent formalin.

It was assumed that the samples in the several collections were being drawn from the same population, *i.e.*, fish moving into the shoals originally were not replaced by other groups of fishes. The fact that areas once seined were not immediately repopulated provides some evidence in support of that assumption. That the mean length (Table 2) or the sex ratios of the specimens in the several collections did not differ significantly from one another offers further evidence.

In the laboratory, the stomach and intestinal contents were examined

[2]All times are Eastern Daylight Time.

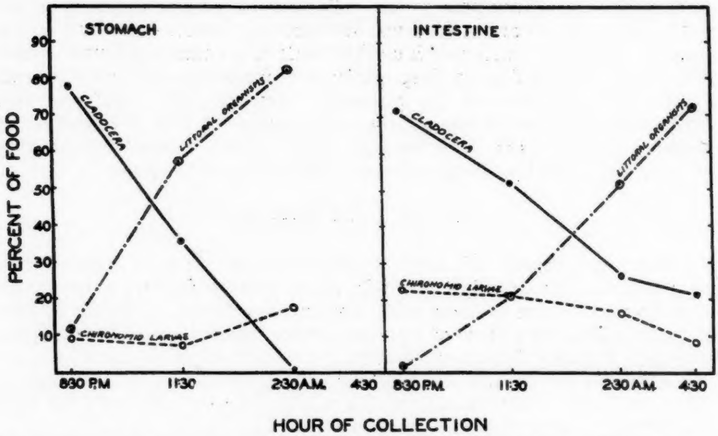

Figure 1.—Variations in the stomach and intestinal contents in the four collections of white perch young from Bantam Lake (from data in Table 2). Fifty specimens were examined in each collection, but only those with food are included in the graph.

for 50 specimens from each of the collections (taken at 8:30 p.m., 11:30 p.m., 2:30 a.m., and 4:30 a.m.). The numbers of white perch in each collection were in excess of 50, but previous experience showed that this number would probably be sufficient to give the information desired. The procedure involved a separation of intestine and stomach. A cut was made in a saggital plane around the stomach wall and the left half removed. The contents of the stomach were examined *in situ* under a binocular microscope. On a series of outline diagrams (Figure 2) the position of the organisms in the stomach was recorded symbolically. An estimate was made on the "fullness" of the stomach (1/8, 1/4, 1/2, 3/4 full, or full[3]). The stomach contents were then emptied and a percentage estimate was made of the volume of each group of organisms. In addition, all individual organisms with the exception of Cladocera, were counted. The contents of the intestine were then examined; the position of the various organisms was diagramatically noted (Figure 2) and estimates made on "fullness" (1/3, 2/3 full, or full, based on the three sections) and abundance of the organisms. Although fragments of organisms found also in the stomach could be easily identified in the intestinal contents, their advanced digested con-

[3]In preliminary examinations a few stomachs were selected as standards to be used in judging "fullness." In the designation one-eighth full, the grouping was arbitrary in that all stomachs judged less than one-quarter full were included. The precision of the estimates is actually irrelevant, since the point based upon this information could as well be made by merely designating the stomachs as "full" or "empty."

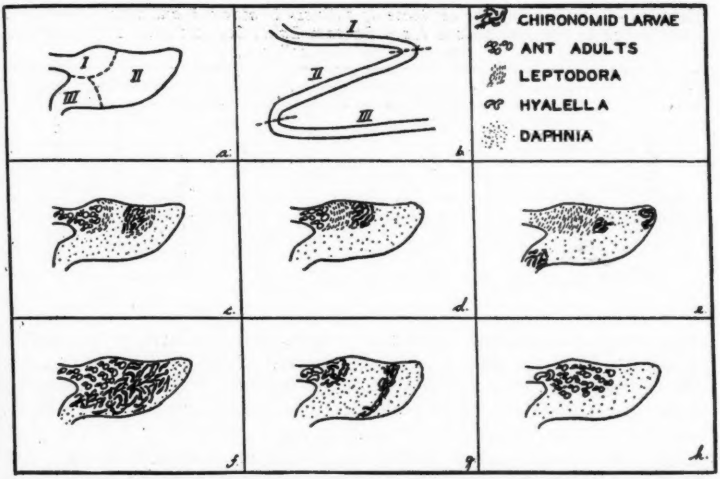

Figure 2.—Diagrams showing the sections of the digestive tract used in designating food position (a, b) and examples of the position of stomach contents (c-h).

dition made any attempt at volumetric estimate subject to considerable error. Consequently, the estimates of abundance of foods in the intestine were roughly designated by plus signs (0, +, . . . + + + +). For comparative purposes a percentage relationship could be established from a summary of these rough estimates that was sufficiently precise for the purpose at hand.

Fullness of the Stomachs and Intestines

The summarized results of the estimates of the "fullness" of stomach and intestine are presented in Table 1. It is apparent that in the 8:30 p.m. collection, about 70 per cent of the stomachs were full of food and 90 per cent were at least half full. In the later collections, the percentage of stomachs with food became progressively less, until in the 4:30 a.m. collection, about 95 per cent of the fish examined had empty stomachs. It is known that the specimens did not disgorge. All available evidence indicates that the several collections were drawn from the same population. It may be concluded, therefore, that white perch in an evening collection had full stomachs and were feeding heavily, and that white perch in the 4:30 a.m. collection had nearly emptied their digestive tracts of food.

It is not irrelevant to discuss the nocturnal movement at this point. From the preliminary examination of the 1940 collection it was as-

Table 1.—Frequency of the estimate of fullness in stomach and intsteine of young white perch in four collections from Bantam Lake, Connecticut. Fifty specimens examined in each collection.

	Stomach			
Estimated fullness	8:30 p.m.	11:30 p.m.	2:30 a.m.	4:30 a.m.
1-full	35	2	1	1
¾	7	6	0	0
½	4	6	1	0
¼	0	9	3	0
⅛	3	17	12	2
O-empty	1	10	33	47
	Intestine			
1-full	16	19	14	3
2/3	33	22	16	7
1/3	1	7	16	27
O-empty	0	2	4	13

sumed that the inshore migration was to be associated with feeding. It is not within the province of the current study to dispute or affirm this assumption. The present evidence indicates that after the young white perch had been on the shoals for a period well under 8 hours, they had almost completely ceased to feed. The fact that the white perch, along with yellow perch, exhibited, on several different occasions, marked inshore movement coincident with fading light, and a similar offshore movement with increasing light, presumably supplies sufficient evidence to conclude that light was the controlling factor of the movement. However, no inference is made that feeding impulses directed the inshore movement, assuming favorable light conditions. It is conceivable, for example, that white perch normally are restricted by daylight to the deeper waters. With the coming of darkness the restriction imposed by light is gradually removed and fish that move shoreward in their swimming find no increase in light intensity to direct their movements back to deep water.

Quantity and Composition of Food

Summaries of food eaten by the white perch in the four collections are given in Table 2. Since empty stomachs contribute no information about food, it follows that the first collection holds the most information and the others increasingly less. The important food organisms in the 8:30 p.m. collection were Cladocera (*Daphnia* and *Leptodora*), chironomid larvae (largely *Tanytarsus*), and a certain adult Hymenoptera. The gradual disappearance of Cladocera from the digestive tract and the increased appearance through the remaining collections, of such forms as *Hyalella*, ant adults, and midge pupae in the fish that were feeding, are believed to be the result of a change in feeding habits rather than chance variation. It is not entirely clear from the information available whether the chironomid larvae are the result of both shallow- and deep-water feeding or are remains of food taken from deep water.

Table 2.—Food of young white perch in four collections from Bantam Lake, Connecticut. The figures are the means of the estimated percentages by volume and are based on the specimens in each collection that contained food.

Food organisms	8:30 p.m.		11:30 p.m.		2:30 a.m.		4:30 a.m.	
	Stomach	Intestine	Stomach	Intestine	Stomach	Intestine	Stomach	Intestine
Chironomid larvae	10	23	7	21	17	16	....	7
Chironomid pupae	2	1	10	1	33	16	....	5
Daphnia	63		29		0		....	
Leptodora	14	71[1]	7	51	0	26	....	21
Hyalella	4	0	30	7	0	16	....	31
Hymenoptera adults	7	0	15	12	36	16	....	26
Ceratopogonid larvae	tr.	0	0	0	0	0	tr.	0
Ephemeroptera nymphs[2]	tr.[3]	0	1	0	14	3	tr.	2
Sialis larvae	0	0	0	0	0	0	tr.	4
Trichoptera adults	0	0	1	0	0	0	....	0
Arachnida	tr.	0	0	0	0	0	....	0
Ostracoda	tr.	4	tr.	7	tr.	5	....	4
Copepoda	tr.	1	tr.	1	0	2	tr.	0
Number of fish with food	47	50	30	48	9	46	1	37
Mean total length (centimeters)	7.4		7.3		7.5		7.4	
Standard deviation of mean	0.5		0.6		0.4		0.4	

[1]Represents combined *Daphnia* and *Leptodora* found in intestine.
[2]Composed of *Neocloeon* and an occasional *Hexagenia*.
[3]Trace.

Position of the Food in the Alimentary Tract

When fishes eat certain foods, it is evident from the relative state of digestion that some items are of recent ingestion while others have been retained for a longer time. The examination of stomachs and intestines of white perch as has been mentioned, then, gives a view of the contents of the alimentary canal in the various stages of digestion. If feeding habits are collectively similar in the population sampled, then the position of the various food organisms in the digestive tract should show similarity. A series of collections, such as has been described, should show a similar progression of the organisms. When the position of the various organisms eaten by these young perch was considered, this expectation was fulfilled.

In the 1940 collection, taken at 9:30 p.m., it was the consistent position of a certain species of *Chironomus* pupae that attracted attention to a consideration of this subject. The pupae were present in 75 per cent of the 50 specimens examined and when present, occurred only in the esophageal region of the stomach;[4] the remainder, and bulk, of the stomach contents was composed largely of Cladocera (mostly *Daphnia*) and *Tanytarsus* larvae. Cladocera and *Tanytarsus* larvae also comprised the food of the specimens not having any of the pupae present. Similar results were noted in the summaries of the 8:30 p.m. collection of 1941. Instead of the *Chironomus* pupae, the most recent food in about 60 per cent of the 50 fish examined consisted of a small winged ant (Formicidae), and scuds (*Hyalella*). The ant adults had

[4]In one specimen, the entire stomach was filled with pupae.

apparently become strewn upon the water's surface during or following nuptial flight, and the young white perch in the 8:30 p.m. collection had just begun to feed upon them. As in the previous year's collection, the remainder (and the greatest volume) of the stomach contents was Cladocera and *Tanytarsus* larvae.

It is not illogical to assume that the Cladocera which formed the bulk of the food in the first collection, were the result of deep-water feeding prior to movement into shoal water, while the recently injested ants and scuds were the result of shoal feeding. The appearance and position in the stomach of *Hyalella,* mayfly nymphs, *Sialis* larvae, Trichoptera adults, etc., in the 11:30 p.m. and the 2:30 a.m. collections are also interpreted as the results of littoral feeding. The nature of this relationship is brought out by the graphical summary of the data of Table 2 (Figure 1). The volume of Cladocera eaten dropped off in both stomach and intestine after the 8:30 p.m. collection, while the volume of "littoral organisms" increased. It should be remembered that increasingly fewer feeding individuals are represented in the estimates after the initial collection. In fact, no computations of percentages were possible for the single stomach that contained any quantity of food in the 4:30 a.m. collection.

The consideration of the individual diagrams of the foods in the stomach suggests that when an individual began to feed upon a particular organism, it continued feeding upon that organism until it was distracted, or for some unknown reason, turned to feed on others. The examination of typical stomach diagrams (Figure 2) illustrates this point adequately. Frequently with the intact stomach contents, it was possible to tease out in "pure culture," the closely compacted clusters of organisms in the order in which they presumably were eaten.

Progression of Food

Since the stomach contents examined exhibited the unexpected dropoff in "fullness" discussed previously, certain anticipated studies of food progression could not be carried out. It is still informative, however, to follow certain organisms through the digestive tract.

If the chironomid larvae and Cladocera were eaten in the deep-water habitat and the ant adults and scuds were eaten in the shoal habitat, then these organisms would be expected to maintain the same relative positions as they moved along the digestive tract, assuming that variations in digestibility of the organisms did not cause different organisms to move at different rates. Such a relationship would be apparent, however, only if individuals in the population tended to feed collectively in a similar manner.

Figure 3 shows the percentage frequency of occurrence of these four organisms in the intestine by collection (from data in Table 3). It is immedately apparent that the plotted values for Cladocera and chironomid larvae behave in a similar way, as do the graphs for ant adults

Table 3.—Percentage frequency of occurrence of chironomid larvae, Cladocera, Hyalella, *and Hymenoptera adults in the three sections of the intestine (designated by Roman numerals—see Fig. 2b) in four collections of young white perch from Bantam Lake, Connecticut.*

[Based only on specimens containing food]

Time of collection	Chironomid larvae			Cladocera			*Hyalella*			Hymenoptera adults		
	I	II	III	I	II	III	I	II	III	I	II	III
8:30 p.m.	63	29	16	60	44	21	0	0	0	0	0	0
11:30 p.m.	21	42	37	36	38	39	42	12	0	67	30	10
2:30 a.m.	11	24	28	4	12	25	29	47	30	27	50	26
4:30 a.m.	5	5	19	0	6	15	29	41	70	6	20	64

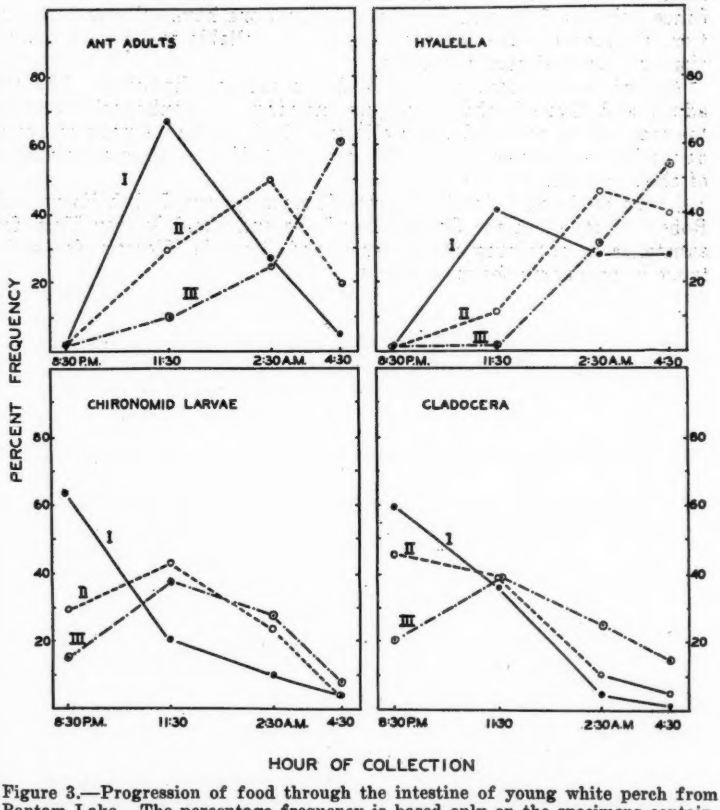

Figure 3.—Progression of food through the intestine of young white perch from Bantam Lake. The percentage frequency is based only on the specimens containing food. The Roman numerals refer to sections of the intestine (see Figure 2b).

and scuds. Verbal descriptions of all the relationships would be space-consuming and unnecessary. As an example, however, the interpretation of the graphic summary of the ant adult is given. In the 8:30 p.m. collection no ants were present in the intestine; in the 11:30 p.m. collection a peak occurred in Section I; in the 2:30 a.m. collection the peak was in Section II; and in the 4:30 a.m. collection the peak was in Section III. The interrelationships of the other organisms may be followed through by study of the figures.

When the position of the stomach food is summarized in the same way, the same similarity exists between the movements of the ants and scuds and between the movements of Cladocera and chironomid larvae. Since only the 8:30 and 11:30 p.m. collections have reliable information, the stomach data are not sufficiently reliable to warrant discussion or graphical representation.

An interesting note may be made on rate of digestion. The ant adults and *Hyalella* that were just entering the esophageal region of the stomach in the 8:30 p.m. collection, had reached a peak of abundance in the lower end of the intestine by 4:30 a.m. after a time lapse of about 8 hours.

I wish to thank Lyle M. Thorpe, Thomas Austin, Ralph Huey, and Robert Moss, all of the Connecticut Lake and Pond Survey Unit, for assistance in obtaining the material and Priscilla Webster for assistance in preparing the manuscript.

THE EFFECT OF COVERING HATCHERY TROUGHS ON THE GROWTH OF CUTTHROAT TROUT (*SALMO CLARKII*)

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Abstract

An experiment was designed and carried out to test the effect of covered troughs upon the growth rate of cutthroat trout. Analysis of the resultant data showed the trout in open troughs to have a significantly greater growth rate than those in covered troughs. The growth rate in open troughs was greater by 13.8 per cent.

Introduction

In the Federal fish hatchery at Bozeman, Montana, it was observed that grayling in the troughs receiving more light appeared to be larger than those receiving less light. A preliminary experiment was made with grayling using a cover for one trough which completely cut out the light. The results from this indicated a difference in growth rates between covered and uncovered troughs.

In hatcheries in general there is considerable discrepancy in the extent to which covers are used on troughs. As no critical test had been made of the effect of covered troughs on the growth of fish, as far as the author knew, an experiment was designed to determine this effect. A species of trout, *Salmo clarkii*, was used as it was believed that the results would be of more general application than if grayling had been used.

From the preliminary experiment it also appeared that the number of fish used might contribute some bias to the results and for this reason different densities of fish were included in the design of the experiment. Lack of trough facilities, however, made it impossible to test more than two different densities.

Experiment

The experiment was carried out at the Bozeman Federal hatchery from October 28 to December 16, 1940. Twelve lots of cutthroat fingerlings were used. Of these six were kept completely covered so that practically no light entered and the other six were left in uncovered troughs. Under each of these treatments, three troughs contained 200 fish each and three contained 400 fish each. Approximately the upper one-half of a standard hatchery trough was used for each lot of fish. All troughs were supplied with water directly from the head trough and the temperature was not variable between troughs. The same food

and proportionately the same amount of food was fed each lot. Lots were assigned to the troughs by randomization.

The criterion used to represent the growth rate of the trout was the average gain in weight per fish per week. The lots were weighed weekly for 7 weeks and the weights of each lot divided by the number of fish in the lot. An accurate record was maintained of the mortality and the numbers of the fish.

Table 1 shows the weights of the lots of fish as taken at weekly intervals and the number of fish in each lot at that time. Figure 1 is the result of plotting the average, individual, weekly weights by treatments against the weekly time interval.

Problem

A consideration of the data as represented graphically does not yield the desired information as to the effect of either covered troughs or numbers upon the growth rate of the trout. However, there appears to be differences in the growth rates under the different treatments. A

Table 1.—Showing weight in ounces and the number of fish in each lot at the time of the weekly weighings

Item	Number of fish	Lot No.	Weeks 0 Weight	Weeks 0 Number	1 Weight	1 Number	2 Weight	2 Number	3 Weight	3 Number
Covered	400	1	16.0	400	18.5	400	20.3	400	22.7	399
		2	15.3	400	17.3	400	19.7	399	22 0	397
		3	14.9	400	16.9	400	19.7	400	21.4	398
	200	4	9.0	200	10.7	200	11.6	200	12.3	200
		5	7.6	200	8.7	200	9.2	193	10.7	192
		6	8.0	200	9.4	200	10.5	199	11.5	199
Open	400	7	14.8	400	17.0	397	19.3	397	22.0	397
		8	15.0	400	17.5	398	19.4	398	22.4	396
		9	15.7	400	18 0	400	21 0	400	23.6	398
	200	10	8.6	200	9.7	200	11.3	200	12.8	200
		11	7.8	200	8.9	200	10.2	200	11.7	200
		12	7.7	200	8.8	199	10.1	199	11.6	199

Item	Number of fish	Lot No.	Weeks 4 Weight	Weeks 4 Number	5 Weight	5 Number	6 Weight	6 Number	7 Weight	7 Number
Covered	400	1	25.5	399	28.6	398	32.9	396	35.0	395
		2	24.8	397	27.2	397	31.2	397	33.0	397
		3	23.5	398	26.0	398	28.0	398		
	200	4	14.0	200	15.4	200	18.0	199	19.3	199
		5	12.3	192	13 5	192	15.4	192	16.5	190
		6	13.0	198	14.8	198	16 8	198	17.5	196
Open	400	7	25.0	397	27.9	396	32.6	396	34.0	392
		8	25.9	396	29.0	396	33.3	394	35.8	392
		9	27.0	398	30.6	398	35.0	398		
	200	10	14.8	200	16.3	200	18.6	199	20.0	199
		11	13.5	200	14.9	200	18.0	200	18.8	200
		12	13.3	199	14.5	199	16.7	199	17.8	198

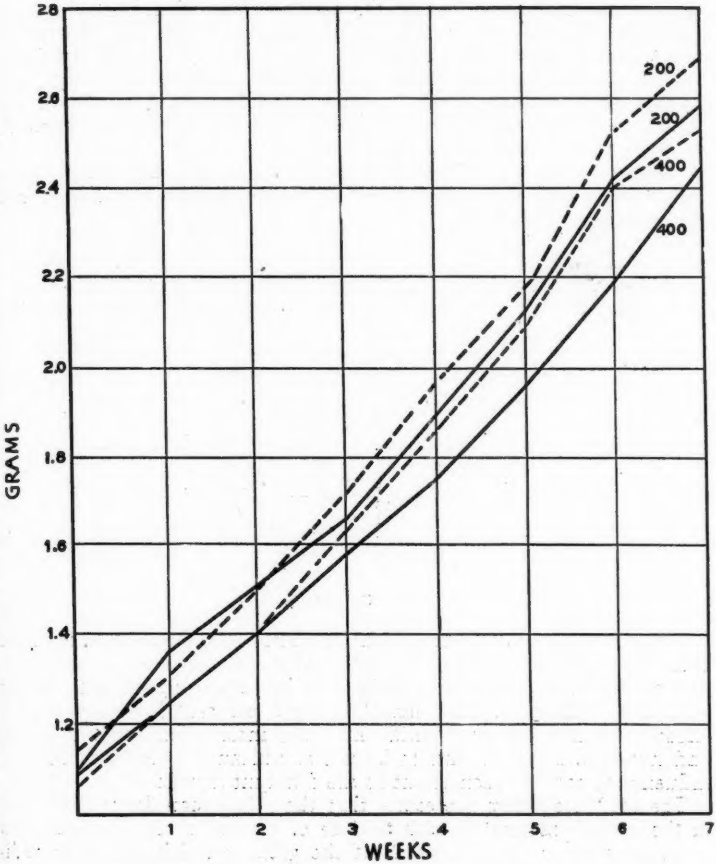

Figure 1.—Showing the average individual weights of the trout in different treatments as plotted against the weeks the experiment ran. Dotted lines represent the treatment without covers and solid lines the covered ones. The numbers at the end of the lines refer to the numbers of fish used in the treatments.

possible solution could be that the variations found in the data associated with the different treatments constitute a single normal distribution—that is, such variations are not significant. The standard design for an analysis of covariance is a suitable method for testing this hypothesis (Snedecor, 1940). Prior investigations have shown that it is necessary to transform original data of this type into logarithms in order to make use of the design.

Table 2 gives the corrected means of gains per fish per week by lots. The means have been averaged for two treatments, one covered and the other uncovered.

Table 2.—Showing the corrected means of gains per fish per week by lots.

Item	Number of fish	Lot No.	Means of Gains (grams)	Average for Treatment
Covered	400	1	0.1922	0.1806
		2	0.1863	
		3	0.1636	
	200	4	0.1705	
		5	0.1846	
		6	0.1866	
Open	400	7	0.2023	0.2057
		8	0.2176	
		9	0.2084	
	200	10	0.1988	
		11	0.2021	
		12	0.2048	

Conclusions

The value for *f* for the treatment in which covers were used is larger than the 1 per cent level in the tables of the *F-distribution;* the effect due to use of covers is thus judged to be highly significant. The *f* value for numbers is much less than the 5 per cent level—hence, the effect of numbers is not significant. The interaction between covers and numbers is also found to be not significant, indicating that the influence of covers is consistent at the different densities.

The evidence shows therefore, that there is a significant difference in the growth associated with the use of covers on the troughs. An average of the corrected means of the gains per fish per week indicates that those raised in troughs without covers showed the greater growth rate. The growth rate of these fish was 13.8 per cent greater than those raised under covers.

The limitations of the results are recognized. In regard to the use of the results in the practice of fish culture, they point chiefly to the necessity of further experiments on the effect on growth of partly covered troughs and perhaps also, of disturbance. By disturbance I refer to that caused by normal hatchery operations; an effect that acts upon the fish in open troughs but not upon those in the covered ones. As this effect was omitted from the design of the experiment, there is

no way to control it in the analysis of data and no way to estimate even whether its effect is positive or negative. In experiments where growth rate is used as a gauge of the effects of some particular treatment upon fish, the results point to the need of considering the factor of relative light as a possible source of bias.

Acknowledgments

Mr. Charles Fuqua, formerly superintendent of the fish hatchery at Bozeman, provided great assistance and the use of facilities at the hatchery; and Dr. C. McC. Mottley and Mr. D. R. Embody, Laboratory of Limnology and Fisheries, Cornell University, generously offered guidance in the design of the experiment and the analysis of the resultant data.

Literature Cited

Snedecor, George W.
1940. Statistical Methods. Third Edition. Iowa State College Press, Ames, Iowa.

RESEARCH IN STREAM MANAGEMENT IN THE PISGAH NATIONAL FOREST

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ABSTRACT

Five years of experimental stream management with 150 miles of trout stream, divided between six watersheds, resulted, after various management practices were tried, in an increase of approximately 300 percent in anglers and in number of fish caught. After the first year, all hatchery fish were marked by fin clipping before being planted. Recoveries from plantings made at different seasons showed a five-fold increase in recovery of spring planted legal-sized trout over trout of near equal size planted in the fall. During the last years of the experiment, emphasis was placed on stocking mainly with legal-sized trout in the spring. Success indicates that this method is the best means of meeting increased fishing demand. Unfavorable practices, such as closing a stream to fishing every other year, were discontinued. Because of the requirement that a complete creel census be taken over wide-spread fishing areas with a limited personnel, a fishing schedule was evolved, staggering the open days for the different streams under an arrangement called "The Pisgah System." While the system permitted only one watershed to be opened at a time, it was found adequate to meet the increasing fishing intensity by spreading the fishing fairly evenly.

INTRODUCTION

The well-watered, forest-covered mountains of the southern Appalachian range comprise a trout fishing area which, until recently, has escaped full appreciation. Formerly difficult of access and jealously held by a limited population of fiercely independent mountain folk, the country was not opened to the free passage of the public until the coming of the lumber industry forced a complete change in the general living conditions of the great majority of its people. The construction of roads destroyed the old privacy while the logging operations, completed for the most part only since the First World War, forced many of the mountaineers from their long-held homesites. The change was completed when much of the mountain country was taken over by the Federal government to be made into national forests. In developing the wildlife possibilities of these forests the U. S. Forest Service, with the cooperation of the U. S. Fish and Wildlife Service and of various State conservation agencies, has inaugurated wildlife management practices which have already borne fruit, enjoyed by both the sportsmen and the lovers of wildlife for its own sake. A great section of the East, extending hundreds of miles south of the Mason-Dixon line, where many northern anglers did not know that trout occurred, is taking its rightful place as one of the outstanding trout areas of the country.

Looking to the intelligent development of the angling possibilities of this region, the U. S. Forest Service and the U. S. Bureau of Fisheries (now a part of the Fish and Wildlife Service) made a cooperative agreement several years ago, one phase of which pertained particularly to the creation of efficient stream-management practices for each of the wildlife management areas in the southern Appalachians. An experimental area was established in the Pisgah National Forest of western North Carolina, through an agreement entered into February 4, 1937. At first the experimental area consisted of the 100,000-acre Pisgah Game Preserve over which the Forest Service held full wildlife jurisdiction. To this, with the consent of the State authorities, was added the adjoining 30,000-acre Sherwood Wildlife Area. From an administrative viewpoint, the two wildlife units belonged together as each was included in the Pisgah Ranger District. From an experimental viewpoint, the two wildlife units also belonged together, for their approximately 150 miles of trout streams, divided into six main watershed groups (Fig. 1) presented a sufficiently extensive experimental area to have significance and at the same time covered most of the types of trout waters found in the region.

The project was begun under the immediate supervision of the late W. M. Keil, Assistant Biologist, U. S. Forest Service. After Mr. Keil's death in January 1939, the author was in charge until the spring of 1942, when the project was considered essentially completed.

Mr. Keil favored the stocking of large trout, a policy he had advocated for years. This idea may be considered the backbone of the Pisgah experimental work, although test plantings of smaller trout have been made. Mr. Keil also located the rearing station where trout were reared for the experimental work, which was built according to his specifications and proved particularly satisfactory. It was also fortunate that the station had in succession two very capable foremen, Reuben O. Knuth and Gerald Bock, who made the most of the facilities available and materially assisted in the scientific work by marking the trout planted and by otherwise cooperating in every manner possible. The Forest Service personnel has carefully and efficiently planted the trout, when, where, and as directed to do so, and, with equal efficiency and care collected the creel census data at the checking stations. The writer was thus fortunate in having the project well started before he took over and in having every contributing factor favorable.

The trout waters of western North Carolina, Georgia and eastern Tennessee are characterized, for the most part, by absence of lime stone. The streams are maintained by a fairly heavy and constant rainfall which varies from 25 inches to as much as 100 inches annually in certain limited sections. The water seeps through the half grown second growth forest to become slightly acid but flows in the rocky stream beds soft, pure, and clear, remarkably free from sediment and all dissolved substances.

Figure 1.—Map of experimental area of the Pisgah National Forest in which stream-management studies were conducted

The streams of the Pisgah Game Preserve and of the Sherwood Wildlife Area are quite typical of these southern Appalachian waters. While varying among themselves, as a whole they may be considered representative. Other southern Appalachian streams probably are better trout waters than any in the experimental area while many are worse, but determinations made in the experimental area should apply equally well to the rest of the region.

The Pisgah Game Preserve and the Sherwood Wildlife Area together make an excellent experimental unit; both are trout areas, yet there are appreciable differences. The Preserve is on the southern slope of a mountain range, has warmer water on the average in which the rainbow (*Salmo irideus*) is the dominant species of trout, with the brook trout (*Salvelinus fontinalis*) persisting in the smaller tributaries. There is a limited population of brown trout (*Salmo trutta*) in the lower waters of two streams. The Sherwood, on the other hand, has a more nearly northern exposure. The colder water permits conditions favorable for brook trout to exist over most of the area and only this species is planted. Some rainbow trout which have migrated from private waters further downstream occur in the lower portions of two of the larger streams.

The original trout population throughout the southern Appalachians, just as further north, was the eastern brook trout. But the western rainbow trout was introduced even before extensive lumbering operations were undertaken. This species eventually came to dominate nearly all the larger trout streams, and many of the smaller ones as well. While no one questions the merits of the rainbow trout, a strong sentiment favors retaining as many brook trout waters as possible. The larger Sherwood streams had been given over to rainbow trout at one time, but the destruction of the fish population as the result of a forest fire permitted a fresh start. This was several years before the area was used for the experimental work.

With the coming of the Civilian Conservation Corps camps in 1933 and 1934, new forest roads were constructed throughout the region, which later became the experimental area. At first the importance of treating both roads and roadbanks to prevent erosion was not realized. The extensive erosion which developed and which was intensified by several cloudbursts during 1936, 1937, and 1938 decreased appreciably the trout-carrying capacity of the streams in the experimental areas, as well as many others in the southern Appalachians. Many plantings of trout were more or less completely washed away by the silt-loaded water. The improved recoveries of the plantings of trout made during 1939, 1940, and 1941 over those made in the earlier years may be credited in part to the fewer floods, resulting in less erosion, and to the new and very efficient practice of the Forest Service in producing plant growth on the roadbanks according to the method developed by the Appalachian Experimental Station.

Streams Included in Experiments

The streams used in these experiments belong to two logical groups according to the wildlife area in which they are found, the Pisgah Game Preserve or the Sherwood Wildlife Area.

In the discussion of the individual streams of the Pisgah Preserve, the Davidson River with its group of tributaries logically comes first. Quite aside from the ability of this stream to furnish good fishing, the Davidson undoubtedly has more friends among the fishermen of the community than has any other stream on the experimental area. It is true that the stream is particularly accessible to the angler, but its friends are not restricted to this group, since it is a beautiful mountain stream in itself, arising in several small tributaries high on the slopes of the Pisgah Ridge and tumbling over boulders and rocks through some 13 miles of forest-banked main stream, finally to leave the National Forest and enter the French Broad River.

Burrows (1935) estimated the stream as B+ in pool grade with an average width over the main section of 47 feet, a depth of 14 inches and a volume of 35,000 gallons per minute. The bottom is predominately rubble, with boulders second in prevalence.

The river has a number of tributaries of varying importance as trout streams, of which eight have been included in the stream management program. These are the following creeks: Shuck, Daniel Ridge, Fork, Laurel, Cove, Grogan, Lookingglass and Avery. The latter two and the Cove are the most important. The Lookingglass has a volume of 12,000 gallons, the Avery 4,500 and the Cove 2,800. Together the eight streams listed have about 20 miles of fishing water, bringing the total for the Davidson drainage to over 30 miles.

During the summer, drift organisms, or those insects which live on land but have fallen into the water, constitute an important portion of the fish food in all streams, but for the year as a whole, those organisms which live on the stream bottom are definitely the most important source of the food of trout. In the Davidson, where many hundreds of square feet of stream bottom were examined, the average weight of organisms per square foot ran from about one and a half grams in midsummer to a little over half that in mid-winter.

The South Mills River, or South Fork of the Mills River as it should more correctly be called, furnishes a contrast to the Davidson. The main stream in the forest is half again as long as the Davidson or approximately 21 miles. The upper third is largely bedrock, the middle third boulders and the lower rubble. The stream warms by late spring to such an extent that conditions are not satisfactory for trout fishing from that time on, although in the upper portion and in the upper half of the middle portion, limited fishing is possible throughout the season.

Burrows gives the South Mills a slightly greater volume than the Davidson, an average width of 35 feet and a depth of 15 inches. The pool grade is given as the same as the Davidson, or B+.

It is difficult to evaluate the richness of the stream in bottom food organisms due to the problem of taking bottom samples which might be considered truly representative. In the bedrock section there are few organisms per unit area while among the boulders the situation is not much better. The stream as a whole must therefore be ranked low in food organisms, probably less than I gram per square foot even in summer.

The South Mills has five tributaries that were included in the experimental setup. Much the most important is Bradley Creek, with its length of 10 miles and its average volume of 9,000 gallons per minute, an average width of 16 feet and an average depth of 10 inches. The Slaterock, Cantrell, Thompson and Poplar Creeks are smaller, adding, together, another 10 miles of trout water.

Third stream in importance in the Pisgah is the North Fork of the French Broad. This watershed is quite the richest in the preserve in bottom food organisms, but is smaller than either of the preceding streams. The portion of it included in the stream management program is not quite 5 miles, but in addition, there are two important tributaries, Courthouse and Kiessee, and two smaller ones, Beetree and Mills Station which add an additional 9 miles.

Burrows assigned to the North Fork of the French Broad the highest possible pool grade and this applies equally well to the Courthouse Creek and Kiessee. The food organisms ran at about 2 grams per square foot through the spring and summer, dropping to 0.75 gram during the winter.

The fourth and last watershed included in the management project is the North Mills, or North Fork of the Mills River. It is smaller even than the North Fork of the French Broad and considerably less productive. Burrows estimated its length as 7 miles, and recorded an average volume of only 8,000 gallons per minute, a width of 14 feet and a depth of 8 inches. The stream bottom consists of boulders and rubble. A small tributary known as the Wash adds about 3 additional miles of rather weak trout water. Another and more important tributary known as Big Creek is not available for fishing purposes as its water is taken for a town water supply.

Altogether there are approximately 46 miles of main stream and 52 miles of tributary water, or 98 miles of trout stream in all, actually under stream management in the Pisgah Game Preserve.

In the Sherwood Wildlife Area all trout waters are branches of the Pigeon River. The two main branches are the West Fork and the Big East Fork. A small third branch is the Little East Fork which, for administrative purposes, has been grouped with the West Fork. The West Fork, in turn, consists of three prongs, known as the Left, Middle, and Right. Altogether with various small tributaries, these branches of the Pigeon furnish some 50 or more miles of brook trout streams. The largest of the individual streams is the Big East Fork, though this is somewhat smaller than either the Davidson or the South Mills.

The Big East Fork has a bottom of boulders and rubble and is only moderately rich in food organisms, running about 1.25 grams per square foot. Also, it has less shade than the other branches and so becomes somewhat warmer. The Left Prong of the West Fork is the richest and best of the three prongs of that fork of the Pigeon. It is quite percipitous, flowing over boulders and some bedrock, and, where rubble does occur, is fairly rich in organisms, with an average of probably one and a half grams per square foot. The Middle Prong is a little less rich while the Right Prong is very nearly barren of all food. The Little East Fork is the richest of all branches of the Pigeon, fully equalling the best sections of the North Fork of the French Broad.

Methods

As originally planned by Keil, the experimental project called for trout of as large a size as could be raised by that time to be planted in the fall. To enable the fish to become as large as possible before being caught, streams were to be opened to fishing only every other year. It was believed more desirable to produce limited good fishing for a few rather than just fair fishing for the many, so not only was fishing restricted to a very limited number of fishing days during a season, but only a limited quota of fishermen were allowed upon the streams on any given fishing day. Some fish were to be marked before being planted, but not necessarily all. All fish caught, however, were to be taken to checking stations to be examined and noted as to species, size, and marks, if any. From the catches made and from bottom-sampling studies showing the degree of richness of the streams in trout food organisms, intelligent modifications of stocking rates could be made. It was understood, however, that the above program was but a start, to be modified at any time as seemed best.

Fish-checking stations were set up at all convenient points to take care of the various streams as opened. Personnel to man the checking stations on open days was furnished by the U. S. Forest Service. Data from the checking stations were to be given to the project leader, and made available to both Services.

Modifications of the plan as originally set up became necessary, practically from the start. Adaptations had to be made to meet special conditions. For example, the waters were too far apart to permit opening all streams on the same day if all anglers were to be properly checked in and out, for limited personnel did not permit more than one or two checking stations at a time. Consequently, only one watershed could be opened on a given day. Also, it was found advisable to restrict fishing to week-ends since at first there were too few anglers at other times to justify operation of checking stations.

As better fishing induced more and more anglers to try their luck in spite of the dollar-a-day fishing permit charge, it soon became apparent that restrictions on the number of anglers were working a

hardship on an increasing number of individuals. There was a tendency toward an undemocratic condition of privilege for the few and disappointment for the many. So, at all costs, it was decided to remove restrictions on the number of anglers participating. But this resulted in overcrowding, particularly on certain days.

Originally, fishing was allowed on a given stream for from three to five or more successive days, once or twice in a season. It was found, however, that not only was fishing much the best on the first day, when the stream was most crowded, but, also, that both the number of anglers and the average catch per angler dropped materially thereafter. Tests showed the decline in fishing was not due to capture of most of the fish, but to the fact that the survivors were too frightened to strike readily within the next few days.

Another practice was to state at the beginning of the season that, after a certain number of fish had been removed, the stream would be closed for the duration of the season. This meant that only on opening day could a fisherman feel sure he could fish a given stream and resulted in uncomfortably crowded conditions the first day.

From such experience, the "Pisgah System," of *"every fishing day an opening day,"* was developed. This system will be discussed in detail later.

Another change from the original plans was concerned with the alternate annual opening and closing of streams. This was attempted with most of the streams for several years, but was finally given up for a number of reasons. The steadily increasing fishing meant increasingly crowded conditions on those streams which were opened. Whether due primarily to the many floods during the early years or to the fact that the streams, for the most part, were not sufficiently rich in trout food organisms to satisfy and hold hatchery fish over the winter, it became increasingly evident that many of the planted trout, particularly those planted in the fall of the year or as 3-inch fingerlings in mid-summer, disappeared before the following season. It is known that some dropped downstream out of the national forest waters. Furthermore, the planted trout which persisted through a closed season rarely made a sufficiently impressive growth to compensate for the decrease in numbers.

The marking of planted trout proved to be of more importance in the experimental work than had at first been realized. After 1937, nearly all trout planted were first marked by clipping off one or two fins. The first year, 1937, only a few plantings were marked. It was found that when sharp clippers were used and the fin removal was complete and close to the body of the fish, regeneration of the severed member apparently never occurred. In clipping the fins of thousands of trout, "slips" obviously were made and incomplete jobs done. More or less complete regeneration then took place which often caused the marking to be overlooked. There is little doubt that figures for the recoveries of marked trout do not do full justice to the actual recover-

ies made. High as the reported recoveries seem to be in some instances, the actual recoveries were probably higher.

At first, single fins were clipped, such as the adipose fin, or right or left ventral. It was intended to give each planting a specific mark of its own. When the supply of single fins suitable to clip ran out combinations of fins were tried. The choice of these combinations was sometimes unfortunate, as, for example, a spring planting in which both pectorals were removed. While the recovery figures from this planting were excellent, showing that the handicap of the particular amputations did not noticeably reduce their chances of survival, the appearance of the fish was such as to cause considerable resentment on the part of the fisherman, who also claimed that the trout so marked were unable to strike at a fly accurately, missing much more frequently than normal fish.

While the marking of all trout seemed esesntial in a program such as that undertaken, it was quickly realized that such marking may be overdone. At first, plantings made in the individual tributaries of a stream were given different markings. It was hoped to learn something of the migration of the fish within the watershed by this means. A little such information was obtained, but only a small proportion of this came from the creel census, as anglers, who often covered an entire watershed in a day, rarely recalled, or were unable to make clear, exactly where they had caught individual fish. After 1938, when the main interest was to determine the relative value of plants made at different seasons of the year, all plantings made during a given season received the same mark.

Three seasons of stocking were recognized: Summer, when plantings of 3-inch fingerlings were made; fall, when the fish were at least 5 inches long and usually from 6 to 7½, or even 8 inches; and spring, when trout were planted which had been carried through the winter from the year before. Practically all these latter trout were at least 8 inches in length, with some individuals 10 inches or even a little longer.

The planting of marked trout was commenced in the Pisgah Game Preserve in 1937, where approximately two-thirds of the trout planted were marked. Unfortunately, although 10,000 good-sized brook trout were planted in the Sherwood Wildlife Area in 1937, none was marked. In that area the first marked trout were planted in the fall of 1938 and so do not appear in the catches until 1939.

A point to be kept in mind is that in the Pisgah Game Preserve where the rainbow trout predominates and the brown trout has a limited position, artificial lures only may be used. Also, for the above species, during the period of the experiments, 8 inches was the minimum length at which they might be legally taken. In the Sherwood, on the other hand, where the brook trout is nearly the only species found, live bait was permissible and the legal minimum length was 6 inches. This may account, in part, for the fact that the average

weight of the individual trout taken in the Pisgah Preserve was half again greater than for the trout in the Sherwood area.

Before leaving the subject of methods, a word should be said concerning actual stocking practice as it was supposed to be followed at all times during the period of the experiments. Mr. Keil proved to the satisfaction of the writer that the full benefits of planted trout may be had only when they are slowly and laboriously spread out, preferably with the aid of pack-cans from supplies held in live boxes. While the size of a stream must guide the efforts of the one doing the planting, and allowances must be made not only for variations in capacity of streams but for different portions of the same stream, Mr. Keil insisted that at any given time not more than three or four should be placed in a pool or other quiet section of water, though the same pool might be planted at intervals during the same day. Hatchery trout associate food with the crowded conditions of hatchery holding ponds. Where dumped in batches, not only are they more easily caught by natural enemies, but their artificially developed gregariousness delays their "return to nature" and natural food habits. It has been observed, when these schools of freshly planted hatchery fish are created, that they frequently tend to drop down stream en masse. Certainly such planting gives the hatchery trout the poorest start possible for their wildlife and materially offsets the care devoted to these fish during the months they were reared in the hatchery.

Experimental Work

The experimental work was performed against a background of trout fishing, since the final proof of stream management must be the degree to which it improves fishing. Table 1 gives a summary of the fishing for the experimental area for each year over the entire period.

As explained under the section entitled "Methods," while a general idea was had at the start of what was wanted, the means of obtaining this end was by no means rigid, so practices were continually modified

Table 1.—Summary of five years' fishing for the entire experimental stream management area

Item	1937	1938	1939	1940	1941	Total
Fisherman days (number of anglers)[1]	1,091	1,112	1,605	2,829	3,563	10,200
Total catch of trout	6,322	5,527	7,667	14,310	18,373	52,199
Number of trout in average catch	5.8	5.0	4.8	5.1	5.1	5.1
Weight of total catch, to nearest pound	......	1,068	1,361	2,744	3,699	......
Weight of average catch, to nearest ounce	......	15	14	16	17	......
Weight, in ounces, of average trout caught	......	3.09	2.84	3.07	3.21	......
Total plants of hatchery trout	39,325	34,118	23,317	24,259	[2]17,592	138,611
Marked hatchery trout in plants subjected to normal fishing	9,500	13,535	16,817	20,234	17,592	77,678
Number of marked trout caught	0	241	1,218	7,013	10,912	19,384
Percentage of marked trout in average catch	0	4	16	49	59	37
Total unmarked trout taken	6,322	5,286	6,449	7,301	7,461	32,819
Number of unmarked trout per angler	5.8	4.8	4.0	2.6	2.1	3.2

[1]Anglers fished an average of about 7 hours per fisherman day. As anglers paid $1.00 for each day of fishing, they usually spent most of the day on the stream, making the day the logical unit of fishing effort in this case.

[2]Does not include trout planted after close of fishing season.

when proved unsuited to meet new conditions. Mistakes were made which had value in showing what should not be done. After the work was completed and a record of improved fishing produced, the information gained was compiled into several more or less interwoven groups of facts, which will be discussed under several headings, although the material all bears on the one essential problem of adding to our knowledge of stream management.

Seasonal Stocking Experiments

All plantings of marked hatchery trout in the experimental area may be divided into two main groups. In the first are those subjected to normal fishing each year after they were planted. In the second group are those planted where they were not exposed to normal fishing. Among these latter are plantings made in certain small out-of-the-way tributaries rarely reach by anglers, and a number of plants, most of them in the fall, in streams that were closed to fishing the following year. These last were made in 1937, 1938, and 1939, when the experimental area was subjected to floods, and at the same time erosion was heavy due to the raw condition of the road banks of the newly built forest roads. This was a combination of adverse factors believed responsible for the washing away of many of the freshly planted fish.

In comparing the relative merits of plants of trout in the summer, in the fall, and in the following spring, it seems only fair to limit comparisons to those continuously subjected to normal fishing. Of the 138,611 marked and unmarked trout which were planted in the 5-year period preceding the close of the 1941 fishing season, a total of 77,678, or 56 percent of the grand total, divided between 39 separate plantings, were marked and planted where they would be properly and normally fished. Five of these were summer plantings of 3-inch fingerlings, 16 were plantings made in the fall of the year of trout from 5 to 8 inches in length, but mostly over 6½ inches, while 18 were plantings of trout carried through the winter and stocked in the spring as 7 to 9 inch trout. Table 2 gives a summary of the recoveries made according to species and season. In the same table are the average weights for these grouped plantings, when made and for each season after planting, when this information is available. Tables 3, 4, and 5 give details of plants for each species.

Since all these plantings are considered normal, it is unnecessary to discuss each individually. Two of the seasonal groups consisted of legal or near legal-sized trout which were immediately available to anglers the next season. They were the trout planted in the fall and trout of the same year class carried through the winter and planted the following spring. These plantings will be considered separately from the group designated as containing summer plantings. The summer plantings consisted of small 3-inch fingerlings that, planted during one fishing season, were rarely big enough to keep the following season and, consequently, were in the streams 2 years before being of

Table 2.—Summary of recoveries and average weights of marked trout Pisgah Game Preserve and Sherwood Wildlife Area

Species	Number recovered	Percent recovered	Number planted	Average weight in ounces: When planted	First season	Second season	Third season	Fourth season
Summer planted trout (average length 3.0 inches)								
Rainbow	30	0.8	4,000	0.21	4.00	3.59	......	......
Brook	18	0.7	2,500	0.24	......	5.79	......	......
Brown	26	0.7	4,000	0.14	3.91	4.50	......	......
All species	74	0.7	10,500	......	......	......	......	......
Fall planted trout (average length 7.5 inches)								
Rainbow	2,008	9.2	21,722	2.45	2.81	3.89	3.96	4.89
Brook	525	6.4	8,230	2.58	2.70	2.89	3.36	3.02
Brown	763	14.3	5,330	1.87	3.12	6.27	6.71	......
All species	3,296	9.3	35,282	......	......	......	......	......
Spring planted trout (average length 8.5 inches)								
Rainbow	6,244	44.5	14,018	4.86	3.65	3.57	......	......
Brook	8,351	58.8	14,188	4.00	3.35	6.30	......	......
Brown	574	15.6	3,690	4.20	3.39	3.51	......	......
All species	15,169	47.6	31,896	......	......	......	......	......

NOTE: Considering the three species together, the ratio between the recoveries of summer, fall and spring planted trout is 0.7 to 9.3 to 47.6 or approximately 1:13:68. The ratio between just fall and spring recoveries is 1:5. For rainbows, it is also 1:5. For the brook trout it is 1:9, and for the browns, approximately 1:1.

Table 3.—Recoveries and average weights of marked rainbow trout arranged according to percentage recovered

[Pisgah Game Preserve and Sherwood Wildlife Area]

Percent recovered	Year planted	Stream planted	Number planted	Number recovered	Average weight in ounces: When planted	First season	Second season	Third season	Fourth season
Summer planted trout									
2.0	1939	Fr. Broad	1,500	30	0.21	4.00	3.59	......	......
0.0	1938	Fr. Broad	2,500	0	0.20	0.00	0.00	......	......
0.8	....	....	4,000	30	0.21	4.00	3.59	......	......
Fall planted trout									
26.2	1940	Davidson	1,000	262	2.94	3.32	......	......	......
19.8	1940	So. Mills	2,000	395	2.83	3.02	......	......	......
13.4	1939	Davidson	2,000	269	2.05	2.90	4.10	......	......
11.3	1940	No. Mills	1,000	113	2.56	1.90	......	......	......
10.8	1940	Fr. Broad	1,200	130	2.93	3.18	......	......	......
10.6	1939	So. Mills	1,487	157	2.37	2.56	4.39	......	......
5.6	1937	Davidson	6,500	366	......	......	......	4.27	4.89
4.8	1938	Davidson	6,535	316	1.47	......	3.18	3.64	......
9.2	....	....	21,722	2,008	2.45	2.81	3.89	3.96	4.89
Spring planted trout									
64.3	1940	So. Mills	1,000	643	5.35	3.30	2.61	......	......
62.4	1941	Davidson	3,332	2,114	5.35	4.19	......	......	......
44.0	1940	Davidson	3,066	1,349	3.80	3.38	4.18	......	......
38.1	1941	So. Mills	2,600	990	5.33	3.87	......	......	......
32.1	1940	Fr. Broad	2,700	866	3.98	3.36	3.93	......	......
21.4	1941	No. Mills	1,320	282	5.36	3.67	......	......	......
44.5	....	....	14,018	6,244	4.86	3.65	3.57	......	......

NOTE: Ratio between the recoveries of summer, fall and spring planted rainbow trout is 0.8:9.2:44.5, or approximately 1:12:56.

Table 4.—Recoveries and average weights of marked brook trout arranged according to percentage recovered

[Pisgah Game Preserve and Sherwood Wildlife Area]

Percent recovered	Year planted	Stream planted	Number planted	Number recovered	Average weight in ounces: When planted	First season	Second season	Third season	Fourth season
Summer planted trout									
1.2	1939	Fr. Broad	1,000	12	0.22	0.00	5.91	......	......
0.4	1939	Little E. F.	1,500	6	0.25	0.00	5.67	......	......
0.7	....	....	2,500	18	0 24	0.00	5.79	......	......
Fall planted trout									
22.6	1940	West Fork	730	165	2.54	2.86	......	......	......
7.9	1939	West Fork	1,000	79	3.14	3.03	......	......	......
7.2	1939	So. Mills	500	36	2.64	2.20	3.00	......	......
5.9	1937	Davidson	3,000	176	......	......	......	3.36	3.02
2.3	1938	West Fork	3,000	69	2.00	......	2.78	0.00	......
6.4	....	....	8,230	525	2.58	2.70	2.89	3.36	3 02
Spring planted trout									
82.7	1941	West Fork	2,720	2,248	4.82	3.28	......	......	......
78.9	1940	West Fork	2,975	2,349	3.79	3.42	......	......	......
62.2	1941	Davidson	830	516	4.40	2.72	......	......	......
52.4	1940	Davidson	743	389	4.35	3.61	6.60	......	......
49.1	1939	West Fork	900	442	2.53	......	......	......	......
45.4	1941	So. Mills	1,250	568	4.48	3.82	......	......	......
45.2	1941	B. East F.	2,520	1,240	3.57	2.94	......	......	......
36.3	1941	L. East F.	1,200	436	3.88	3.03	......	......	......
15.5	1940	So. Mills	1,050	163	4.15	3.99	6.00	......	......
58.8	....	....	14,188	8,351	4.00	3.35	6.30	......	......

NOTE: Ratio between the recoveries of summer, fall and spring planted brook trout is 0.7 to 6.4 to 58.8, or approximately 1:9:84.

Table 5.—Recoveries and average weights of marked brown trout arranged according to percentage recovered

[Pisgah Game Preserve and Sherwood Wildlife Area]

Percent recovered	Year planted	Stream planted	Number planted	Number recovered	Average weight in ounces: When planted	First season	Second season	Third season
Summer planted trout								
0.7	1939	So. Mills	4,000	26	0.14	3.91	4.50	......
Fall planted trout								
32.3	1938	So. Mills	1,500	484	1.86	......	3 80	6.71
7.3	1939	So. Mills	2,930	215	1.52	2.96	8.75	......
7.1	1940	So. Mills	900	64	2.24	3.28	......	......
14.3	....	....	5,330	763	1.87	3.12	6.27	6.71
Spring planted trout								
28.2	1941	So. Mills	820	231	4.78	3.87	......	......
16.0	1940	So. Mills	1,870	300	3.17	3.16	3.51	......
4.3	1941	No. Mills	1,000	43	4.64	3.14	......	......
15.6	....	....	3,690	574	4.20	3.39	3.51	......

NOTE: Ratio between recoveries of summer, fall and spring planted brown trout is 0.7 to 14.3 to 15.6, or about 1:20:22.

interest to anglers. In the experiments undertaken the summer plants were fewer than either fall or spring plants and so their results can be given less weight.

Of the 16 plantings made in the fall, 8 consisted of rainbow trout, or 21,722 fish; 5 of brook trout, numbering 8,230; and 3 of brown trout, amounting to 5,330; a total for the three species of 35,282 fish. The 18 plantings of the same year class of trout held through the winter and planted in the spring consisted of 6 plantings of rainbow trout or 14,018 fish; 9 of brook trout, totalling 14,188 fish; and 3 of brown trout, or 3,690 fish; a total of 31,896 fish.

While Tables 2, 3, 4, and 5 give recovery details, some of the data deserve emphasis by repeating them here. Averaging together the three species, the ratio between the percentage recoveries of the fall and spring plants of trout is 9.3 to 47.6, or approximately 1 to 5. For the rainbow alone the ratio was about the same, while for the brook trout the ratio was about 1 to 9.

The fact that for the brown trout (Table 5) the ratio was about 1 to 1 requires some explanation for being so out of line with the other two species. It is not believed that the brown, as tried in the Pisgah, had an opportunity to show itself at its best. Conditions as they existed in the waters where brown trout were planted, particularly in the lower half of the South Mills which received most of the plants of this fish, were not favorable to any trout. As explained elsewhere, this was mainly due to the degree to which this section of the river warmed up in summer. Under such circumstances the fall-planted trout had a temporary advantage over those planted in the spring, for the fall fish had several months to become adapted to living in the stream, while the spring fish were exposed almost at once to the summer heat. It is suggested that under such circumstances a greater proportion of the later planted browns might drift away. Reports were received of marked brown trout being taken below the national forest boundaries, so there is no question that some of these fish attempted to escape the unfavorable conditions by migrating downstream. Plants of brown trout were discontinued in the experimental areas after 1940.

But accepting the average recoveries as they stand, we still have a 5 to 1 ratio in favor of holding trout over the winter and planting them in the spring, rather than in the preceding fall. If trout are reared to about legal size by fall, as they can be at the Davidson River station, for example, they can be carried through the winter on a maintenance diet at very slight extra cost. A bare maintenance diet also tends to condition the fish, so that when planted they need not be lacking in firmness and gamy quality.

The argument has been advanced against the planting of legal-sized hatchery trout that they are so inferior to wild trout that it is to the discredit of state or government to produce them. It is true that hatchery fish can usually be distinguished from wild fish by anyone familiar with them, largely by their lack of natural color. In addition, if re-

cently force-fed and overfat their lack of gamy quality may be a recognizable feature. This last characteristic improves with time and, as stated, may be less apparent when the fish are conditioned.

It is apparent that the intensity of the fishing must be the basis for determining the number of hatchery fish to be planted. The native fish population will maintain a certain degree of fishing by itself. When fishing pressure goes above that point, sufficient hatchery fish to maintain a fair catch should be added. It must be remembered, however, that the natural food supply of the stream is limited and that all planted fish which are too small to be included in the angler's catch reduce the capacity of the stream to support larger fish. As fishing intensity increases, the hard fact becomes evident that from the point of view of the immediate interests of the angler, all fish in the stream under legal size are a detriment.

This does not mean that there should be any intentional destruction of undersized fish but with fishing intensity high and large trout needed to meet the immediate demand, the stream's limited fish food supply can best be utilized by fish that are available to the angler.

It is agreed that all encouragement should be extended the native fish which does not cut down on total catch. Contrary to the findings of Hazzard and Shetter (1935) our results indicate that the planting of legal-sized hatchery fish tends to protect the native trout. Not merely is the fishing strain as measured by total fishing effort on the larger wild fish reduced, but the large hatchery fish which escape the wiles of the angler have a chance to spawn and so build up the supply of "native" fish. As shown in Table 1, the catch of native or unmarked trout appears to have remained remarkably constant throughout the five years of experimental effort, when the total catch increased 300 percent.

A glance again at Table 1 shows that in 1937 the take of unmarked trout in the experimental area was 6,322. These were doubtless mostly native fish in the sense that they had lived all their lives in the stream, though a few may have been planted as three-inch fingerlings.[1] No marked trout were available that year. In 1941, when fishing intensity had increased 300 percent, the number of unmarked trout taken numbered 7,461, though the marked fish taken numbered 10,912. For the five years of fishing, the annual take of unmarked fish averaged 6,564. This suggests that a figure somewhere in the neighborhood of this number may be considered the normal available annual population of legal-sized trout for the experimental area. Assuming this figure to be conservative, the upper limit probably would not exceed 10,000.

Even if we accept this higher figure, there would not be enough fish to supply the demand as it existed for this area after 1939. The annual number of fishermen days in 1937 was 1,091; in 1938, 1,112; in 1939, 1,605; while by 1940, it had jumped to 2,829, when 14,310 trout were caught; and by 1941, to 3,563, when 18,373 fish were taken. What

[1]A few such plantings were made before the experiments were begun.

the limit might be is hard to say. War and other disturbing factors make one hesitate to make a guess, but 5,000 fishermen days of fair fishing is probably not an unreasonable figure. It is interesting to note, too, that such a number of daily permits sold would about cover the costs of raising and distributing the hatchery fish.

To recapitulate: The function of stocking with hatchery fish is to support the excess fishing to which a stream may be subjected above that which the stream can supply by natural reproduction. The group natural capacity of streams in the experimental area would appear to be not over 10,000 legal-sized fish per year. Fishing demand exceeded this figure after 1939. In other words, after this date, the streams had to satisfy a fishing demand which required more legal-sized trout than the limited fish food supply could possibly grow, or even support for long.

This demand was met by the planting of legal-sized fish in the spring. Not only were a greater number of larger trout made available to the angler but at a materially lower cost to the government for each pound of trout in the fisherman's creel. The greater number of big trout available meant better fishing. Better fishing meant more fishermen. More fishermen meant a greater income from fishing permits. A greater income points the way toward a self-sustaining sport. The logical goal of wildlife management must be a balanced budget.

Before concluding this section, a word should be said regarding the planting of small trout. Table 2 shows the recoveries made from a few plants of three-inch fingerlings. With the streams of the experimental area tending to be more or less crowded with medium- and larger-sized fish, plants of small fish were at a disadvantage from the start. At that, the recoveries were as good as might be hoped for under the circumstances. It is probable that the planting of small trout still has a

Table 6.—Summary of 5 years' fishing in each of the two sections of the experimental stream management area

Item	1937	1938	1939	1940	1941	Total
Pisgah Game Preserve						
Fisherman days (number of anglers)[1]	341	667	969	1,700	2,333	6,010
Total catch of trout	1,155	2,468	3,304	7,090	10,418	24,435
Number of trout in average catch	3.4	3.7	3.4	4.2	4.5	4.1
Weight of catch, to nearest pound	......	588	755	1,485	2,373	......
Weight of average catch, to nearest ounce	......	14	13	14	16	......
Average weight, in ounces, of trout taken	......	3.82	3.66	3.35	3.64	......
Total marked trout taken	0	241	743	4,131	6,684	11,799
Percentage of marked trout taken	0	9	22	58	64	48
Sherwood Wildlife Area						
Fisherman days (number of anglers)[1]	750	445	636	1,129	1,230	4,190
Total catch of trout	5,167	3,059	4,363	7,220	7,955	27,764
Number of trout in average catch	6.9	7.4	6.8	6.4	6.5	6.6
Weight of catch, to nearest pound	......	480	606	1,259	1,326	......
Weight of average catch, to nearest ounce	......	18	15	18	17	......
Average weight, in ounces, of trout taken	......	2.51	2.22	2.79	2.67	......
Total marked trout taken	0	0	475	2,882	4,228	7,585
Percentage of marked trout taken	0	0	11	40	53	27

[1]Anglers fished an average of about 7 hours per fisherman day. As anglers paid $1.00 for each day of fishing, they usually spent most of the day on the stream, making the day the logical unit of fishing effort in this case.

place in management work, in lakes, or possibly in streams where the fishing is not heavy, but it is definitely inadequate where fishing is intense. Also, it is so easy to overstock with small fish. When too many large trout are planted, they may be a little too easily caught, until the fish population is reduced to one the stream can support. It is far better to catch and use the excess fish than to wait and let them starve, as must happen when the excess fish are small.

Overstocking Studies and Special Problems of the Different Streams

Quite unintentionally the experiments included overstocking studies involving a good share of the experimental streams. In briefly touching on the special problems of the individual watersheds, this phase of the management studies will be emphasized. Associated with the problem of overstocking in several instances was the practice, at first, of closing streams to fishing every other year. As a result, many of the plantings had to be considered as abnormal, since the streams were closed to fishing the following season.

It cannot be overemphasized that it is the failure to realize how limited the fish food in a stream may be, and how impossible it is to meet a heavy fishing demand with plants of small trout, a practice which has been at the root of most of the unsatisfactory stocking efforts. The Davidson, during the early years of the experimental work, was a good example of overzeal in building up fishing. The main stream was overstocked with rainbow in 1937 and 1938. In the fall of 1937, a total of 6,500 rainbows, about 5 inches or more in length were planted. The following fall, 1938, the plant was 6,535 rainbows of about the same size with an average weight of 1.47 ounces. While the fishing was better in 1938 than in 1937, this heavy plant in the fall of 1938 appears to have hurt the 1939 fishing. As Table 7 shows, the number of trout taken from the Davidson dropped from 1,929 in 1938 to 1,116 in 1939, and the number of trout in an angler's catch dropped from an average of 3.7 weighing 14 ounces to 3.2 trout weighing 11 ounces, while the anglers complained in 1939 that the Davidson seemed full of small trout with few worth keeping.

In the fall of 1939, only 2,000 rainbow trout were planted in the

Table 7.—Summary of 5 years' fishing in the Davidson River, Pisgah Game Preserve

Item	1937	1938	1939	1940	1941	Total
Fisherman days (number of anglers)[1]	224	519	350	728	1,175	2,996
Total catch of trout	627	1,929	1,116	3,454	5,405	12,531
Number of trout in average catch	2.8	3.7	3.2	4.7	4.6	4.2
Weight of catch, to nearest pound	......	444	244	756	1,292	......
Weight of average catch, to nearest ounce	......	14	11	17	18	......
Average weight, in ounces, of trout caught	......	3.68	3.50	3.50	3.82	......
Total rainbow trout taken	578	1,735	955	2,869	4,361	10,498
Total brook trout taken	49	194	161	585	1,033	2,022
Total brown trout taken	0	0	0	0	11	11
Percentage of marked trout taken	0	12	18	60	62	42

[1]See footnote 1, Table 6.

Davidson and 3,066 were carried through the winter and planted in the spring of 1940. This moderate-sized planting resulted in a remarkable improvement in the following season's fishing. Fishermen days in 1940 were twice the number in 1939, because of the improved fishing, while the take of fish jumped 300 percent with the fish retaining the same average weight. Individual catches increased to 4.7 fish, weighing 17 ounces. By this time it was realized that a step in the right direction had been taken. To be on the safe side, in spite of the increased fishing, again only 2,000 rainbows were planted in the fall of 1940 and 3,332 in the following spring, though, because of poaching from the winter holding pool, the spring plant was somewhat below the figure originally set up. The 1941 season was beyond anything officially hoped for. Fishermen days went up another 100 percent from the 1939 figure, while the take of trout jumped from 3,454 to 5,405, having a weight of 1,292 pounds. The weight of the average creel of trout increased to 18 ounces, though there was a slight drop in the number of trout in the average catch from 4.7 to 4.6.

Probably the best example of overstocking was found in Cove Creek, a tributary of the Davidson. In October, 1937, 2,000 seven-inch brook trout were carefully distributed over 2½ miles of stream. Brook trout had once thrived in this fine forest stream and at the time both brook and rainbow were present in limited numbers. It was hoped that such a large plant of brook trout would definitely tip the scales toward this species and that Cove Creek would once again become a good brook trout stream. The stream was checked several times during the winter, while the water was still cold, and the fish found to be in fair shape. Unfortunately, the fish were not checked in the spring when water temperatures began to rise and the metabolic activities of the fish increased, but it became evident later that food demands far exceeded the available supply.

When the fishing season opened, a special checking station was set up at the creek, occupied by Mr. Keil and the writer, to give particular attention to the fish of this stream. The results were a complete disappointment. The trout were found to be in a starved condition and resembled small eels in appearance. Most anglers refused to keep them. The plant was a failure and no trace of it could be found the following year. Careful checks showed that no migration had taken place, which was substantiated by the fact that no brook trout was taken in the Davidson within two miles of Cove Creek.

Evidence was obtained of overstocking in the North Fork of the French Broad in the early days of the experimental work. In the spring of 1938, a plant of 2,300 rainbows between 6 and 7 inches long was made, and another plant that fall of 5,000 five-inch fingerlings of the same species. These plants were excessively large and the closure of the stream in 1939 appears to have effectively spoiled any possible benefits from either plant. The spring-planted fish were too small to figure in the 1938 catches and only 7 showed up in the catches made in

1940. The plant was not represented in the 1941 catches. The fall plant provided the anglers with 12 fish in 1940 and 48 more in 1941.

The excellent showing of the stream in 1940 was due mostly to a spring plant of legal-sized fish which made up more than half the catch. However, the plant itself was excessive. Of the 2,700 trout placed in the river, only 30.4 percent were recovered the first season.

So many trout appeared to remain after the season was over that no plant was made the following spring. This proved to be a mistake, and, though 1,200 rainbows were planted in the very late fall of 1940, the 1941 catch was materially below that of 1940.

Table 8.—Summary of 5 years' fishing in the North Fork of the French Broad River, Pisgah Game Preserve

Item	1937	1938	1939	1940	1941	Total
Fisherman days (number of anglers)[1]	53	99	Stream Closed	282	220	654
Total catch of trout	326	397		1,557	1,036	3,316
Number of trout in average catch	6.1	4.0		5.5	4.7	5.1
Weight of catch, to nearest pound	......	92		298	194	......
Weight of average catch, to nearest ounce	......	15		17	14	......
Average weight, in ounces of trout caught	......	3.73		3.07	2.99	......
Total rainbow trout taken	245	349		1,273	824	2,691
Total brook trout taken	81	48		284	212	625
Total brown trout taken	0	0		0	0	0
Percentage of marked trout taken	0	0		54	26	33

[1]See footnote 1, Table 6.

The catches made in the South Mills River are shown in Table 9. Great things were expected of this stream, so it was heavily stocked in 1937 and 1938, and in addition, was closed to fishing in 1938. Possibly, considering how poor the stream is in trout food, the disappointing returns of 1939 and 1940 should have been expected. It is a magnificent mountain stream, which had had an excellent fishing reputation before the timber had been removed from the watershed. So it had seemed capable of absorbing all the trout which could be planted and returning them to the angler bigger and better. This the South Mills quite failed to do, and by 1940, the lesson had been learned. Plantings were reduced and, as shown by the 1941 catches, the actual fishing capacity appeared to have been gauged and properly met. With almost an identical number of fisherman days for 1940 and 1941, the catch of the latter showed a 50 percent increase over the preceding year, with the average trout caught in 1941 slightly heavier than in 1940.

In the earlier description of the stream it was stated that much of the upper portion of the river flows over bedrock, where food organisms are seldom found outside limited and restricted pockets of gravel. Furthermore, the stream warms up excessively over the lower half, where natural enemies of the trout occur. These include black bass, rock bass, and animals of uncertain value such as stream lampreys and the large amphibian, ***Cryptobranchus***, or hellbender. There is some evidence that satisfactory spawning conditions are not available, for natural reproduction is either low or the young trout are destroyed

by their enemies. Certainly, in no other stream in the experimental area have the hatchery trout come to comprise so large a proportion of the average catch. In 1941, hatchery fish constituted 82 percent of the total take of trout.

Even before the experimental work was started, it was realized that brook and rainbow trout were not doing well in the stream, so brown trout were introduced. It may be that most anglers were not sufficiently skilled to take brown trout when restricted to artificial lures. Possibly the species was overstocked at first, or, as has been suggested, the water became too warm before the end of the summer. Whatever the reason, brown trout have never given evidence of being as satisfactory in the South Mills as the rainbow trout. So, after the spring

Table 9.—Summary of 5 years' fishing in the South Mills River, Pisgah Game Preserve

Item	1937	1938	1939	1940	1941	Total
Fisherman days (number of anglers)[1]	50	Stream Closed	548	690	694	1,982
Total catch of trout	174		1,977	2,083	3,119	7,353
Number of trout in average catch	3.5		3.6	3.0	4.5	3.7
Weight of catch, to nearest pound	......		464	431	717	......
Weight of average catch, to nearest ounce	......		13	10	16	......
Average weight, in ounces, of trout caught	......		3.76	3.31	3.63	......
Total rainbow trout taken	169		1,346	1,279	2,038	4,832
Total brook trout taken	5		53	245	637	940
Total brown trout taken	0		578	559	444	1,137
Percentage of marked trout taken	0		31	68	82	65

[1]See footnote 1, Table 6.

of 1941, the planting of brown trout in any waters of the experimental area was discontinued.

As previously stated, the South Mills was closed to fishing in 1938. One of the most interesting plants in this stream was one of 2,670 rainbows made in the spring of that year. The take of this planting in 1939, when these fish were first exposed to fishing, was 26. Five more were taken in 1940 and 8 in 1941, a total recovery of 39 or 1.5 percent. Of 1,700 brook trout planted the same season in the tributary waters, only 7 were recovered in 1939, 5 in 1940, and 1 in 1941. A planting of 2,520 brown trout, made the same season, gave a total of 9 trout in 1939, 4 in 1940, and an additional 4 in 1941.

Of the original planting of 5,560 brown trout in the fall of 1937, 107 were taken in 1939, 194 in 1940, and 11 in 1941, a total of 312 or 5.5 percent. There have been persistent reports of many of these early as well as later planted brown trout being caught below the national forest boundaries.

Additional evidence of fishing lost from closing a stream for a season is provided by the North Mills. In the fall of 1938, a planting of 2,143 rainbow trout was made in this stream. Only 37 were recovered in 1939, and, since there was no fishing in 1940, the only additional recoveries were 11 fish in 1941. This gives a total recovery of 47 or 2.2 percent. Another plant of 2,000 rainbow trout was made in the fall of 1939. In view of the fact that only 13 of these were taken in 1941,

Table 10.—Summary of 5 years' fishing in the North Mills River, Pisgah Game Preserve

Item	1937	1938	1939	1940	1941	Total
Fisherman days (number of anglers)[1]	Stream Closed	49	71	Stream Closed	244	364
Total catch of trout		142	211		858	1,211
Number of trout in average catch		2.9	3.0		3.5	3.3
Weight of catch, to nearest pound		52	47		181	......
Weight of average catch, to nearest ounce		17	11		12	......
Average weight, in ounces, of trout caught		5.86	3.59		3.37	......
Total rainbow trout taken		142	211		733	1,086
Total brook trout taken		0	0		80	80
Total brown trout taken		0	0		45	45
Percentage of marked trout taken		0	18		64	48

[1]See footnote 1, Table 6.

it is interesting to speculate how many might have been caught in 1940.

Turning to the Sherwood, we find further proof of the undesirability of closing a stream to fishing after being stocked. Here, too, the value of spring plantings of legal-sized fish is quite apparent.

Table 11 gives a summary of 5 years' fishing in the West Fork and the Little East Fork. The necessity of combining the data for these streams to avoid confusion is possibly better appreciated if it is explained that in 1937 the entire area was opened to fishing. In 1938, two of the three prongs of the West Fork were closed to fishing, while the third and the Little East Fork were opened together. In 1939, the Little East Fork and its associated prong of the West Fork were closed while the other two prongs of the West Fork were opened. In 1940, the Little East Fork and the West Fork were opened, but they were opened separately.

In studying the table, it may help if it is recalled that all of both the Little East Fork and the West Fork were opened to fishing in 1937, 1940 and 1941, and about half the combined fishing waters were available to fishing in 1938 and 1939.

The drop in fishermen days in 1941, in spite of a higher average catch than the year before, is attributed to three reasons: The Big East Fork was opened to fishing in 1941, but only for one day in 1940; the improved fishing and larger trout of the Pisgah Game Preserve were claiming many of the anglers who previously fished the Sherwood;

Table 11.—Summary of 5 years' fishing in the West Fork and Little East Fork of the Pigeon River, Sherwood Wildlife Area

Item	1937	1938	1939	1940	1941	Total
Fisherman days (number of anglers)[1]	513	445	272	1,015	685	2,930
Total catch of trout	3,659	3,059	1,783	6,628	4,919	20,048
Number of trout in average catch	7.1	7.4	6.6	6.5	7.2	6.8
Weight of catch, to nearest pound	......	480	246	1,158	825	......
Weight of average catch, to nearest ounce	......	18	14	18	19	......
Average weight, in ounces, of trout caught	......	2.51	2.20	2.80	2.68	......
Total rainbow trout taken	1	0	2	1	6	10
Total brook trout taken	3,658	3,059	1,781	6,627	4,906	20,031
Total brown trout taken	0	0	0	0	7	7
Percentage of marked trout taken	0	0	27	43	58	31

[1]See footnote 1, Table 6.

and, associated with this second reason, is that of the smaller average weight of the trout taken in the West Fork in 1941 over those taken in 1940, though they were still ahead of 1938 and 1939 in this respect.

It is natural that with the varying combinations of open and closed streams for the different years it is impossible until the last two years to distinguish the normal plants of marked trout in these waters. Also, it is natural that in collecting data during the earlier years some confusion developed at times. One instance of such confusion occurred in 1940 when the Little East Fork and the entire West Fork were opened at the same time and when fishermen days increased to 400 percent of what they were the year before.

A planting of 1,000 brook trout was made in the fall of 1938 in the Little East Fork which was closed in 1939. A planting of 1,900, with the same mark, was made in a prong of the West Fork in the spring of 1938, a prong which was closed to fishing that year. Only 23 fish with this mark were taken in 1939 from the West Fork. In 1940, anglers took 352 with this mark from the combined streams. A study of the original data sheets indicates that most, if not all, of these fish came from the Little East Fork. This, if true, is the most remarkable survival of fall-planted trout observed.

While the writer does not consider that the evidence justifies placing the planting with the normal plantings, he believes that certain circumstances may have made it possible. The Little East Fork planting was made in a stream in which such fish as occurred were of the same species. The stream had been almost completely depopulated of trout from poaching, but from the time of the plant received far better than average protection. It is by far the richest of all the Sherwood waters in bottom food organisms.

Finally, as stated above, of the 1938 spring planting in the West Fork, only 23 were recovered in 1939, so it is unlikely that more than this number were taken in 1940. Even assuming the most cautious attitude and combining the plants, which were both made in 1938, and so were subjected to two winters, the 1940 catch of 12.1 percent of the combined original plantings was remarkable.

If the recovery was entirely that of the Little East Fork planting, the percentage recovery becomes 35.2 percent, which is phenomenal under the circumstances. Certainly, it is a contrast with a planting of 1,000 made in the right prong of the West Fork in the fall of 1938. A cloud burst washed out the stream before the next fishing season, and not one member of this plant was ever recovered.

Before leaving the West Fork it may be of interest to point out that among the normal spring plantings of brook trout in this water are probably some of the most successful recoveries of planted trout on record. A planting of 2,720 brook trout with an average weight of 4.82 ounces each in 1941 gave a recovery of 82.7 percent, while a planting of 2,975 with an average weight of 3.79 ounces in 1940 gave a recovery of 78.9 per cent.

Table 12.—Summary of 5 years' fishing in the Big East Fork of the Pigeon River, Sherwood Wildlife Area

Item	1937	1938	1939	1940[1]	1941	Total
Fisherman days (number of anglers)[2]	237	Stream Closed	364	114	545	1,260
Total catch of trout	1,508		2,580	592	3,036	7,716
Number of trout, in average catch	6.4		7.1	5.2	5.6	......
Weight of catch, to nearest pound	......		362	101	501	......
Weight of average catch, to nearest ounce	......		16	14	15	......
Average weight, in ounces, of trout caught	......		2.24	2.72	2.64	......
Total rainbow trout taken	36		55	95	326	512
Total brook trout taken	1,472		2,525	497	2,710	7,204
Total brown trout taken	0		0	0	0	0
Percentage of marked trout taken	0		0	7	45	18

[1]Opened to fishing one day only.
[2]See footnote 1, Table 6.

Table 12 gives a summary of fishing for the Big East Fork. This stream is essentially one unit, or river, as compared with the West Fork which is divided into three prongs, that together have less volume of water than the Big East Fork. As a whole, the Big East Fork has never been as popular among anglers as the rest of the Sherwood's trout streams.

As the table shows, the stream was closed to fishing in 1938 and was to have remained closed in 1940, but was opened one day of that year to see if the effects of a cloudburst in August could be noted. After the original planting of unmarked hatchery trout in 1937, no planting was made until the fall of 1939, when 2,000 brook trout were stocked, followed by a stocking of 1,000 in the spring of 1940. On the one day 497 brook trout were taken, 13 of which belonged to the fall planting and 30 to the spring planting. During the entire fishing season of 1941, 16 more of that fall planting and 25 more of the spring planting were taken. Whatever additional lesson may be learned from these figures, it is apparent that good fishing was lost by not opening the Big East Fork for more than the one day in 1940. Probably fishing was lost by the 1938 closure, but this is not readily apparent from the figures.

In comparing the total take of trout for the 5-year period for the Big East Fork with that from the combined Little East Fork and West Fork, it is not concluded that the ratio between the catches gives a true picture of the relative merits of the two bodies of trout water. It is now realized that the Big East Fork was not handled so as to have permitted the stream to show its full possibilities. In other words, it is a better trout stream than its record indicates.

The Pisgah System

The Pisgah System of "every fishing day an opening day" is frankly a compromise system of stream management built on the requirement that exact records of the fish caught be kept and the unfortunate necessity in the Pisgah experimental area of restricting the waters opened to fishing on a given day to those covered adequately by one or two checking stations.

This system may be described as that stream management practice

whereby fishing in a given wildlife area is restricted to one stream and its tributaries on any given day, while the number and distribution of the open days is determined by the stream's relative fishing capacity, its physical condition and the desirability of completely resting it from fishing for as long as possible after each open day.

Relative fishing capacity of a stream depends in part on richness in bottom food organisms, on shelter, on the extent of good fishing areas, on size, and to some extent, on degree of popularity. This ranking may be more or less arbitrary and subject to change each year. It may be defined as the proportional capacity of a stream to furnish fishing in relation to the total fishing of the area as a whole. If, for example, under a certain fishing load, a given district is believed able to furnish 100 days of fishing, it may be decided that one large stream alone can supply 30 of them. Another stream possibly can furnish equally good fishing for 20 days, four others 10 days each, and two, neither very large, nor located where they can be conveniently included in a season with other streams, fish days each. This is merely a sample. The possibilities are endless.

The factor in physical condition that is probably most important in the experimental area is the average summer temperature of the water. A stream may warm up to such an extent by the end of June that the trout practically cease to strike. Its open days, therefore, should be before that time. Another stream, having sufficiently cold water throughout the season, may have the majority of its open days in July and August.

Resting a stream from fishing for as long as possible after each open day is of great importance in assuring a good catch, where fishing is subjected to the handicap of comparatively crowded conditions. While trout may seem to recover quickly from fright, there is very good evidence that they retain a greater degree of caution for some time. Where frightened by several successive days of intensive fishing, this wariness becomes fixed for a considerable period.

The expert angler likes to pit his cunning against the wariness of the trout. The more suspicious the fish the better such an angler likes it, for to him the pleasure lies in the sport itself and not in the fish caught. He is a real sportsman, well deserving of praise.

It is usually a waste of breath to suggest to such an angler that a trout may carry cautiousness too far. But the stream manager must not permit his natural inclinations to spoil his perspective of the problem as a whole. He wants the trout he places in the streams to furnish sport, but he also wants them caught or the expense of placing them in the stream is lost. To him, wariness by the fish may indeed be overdone. Pisgah experimental area records show that but few planted trout, not caught one season, survive to the next.

After the new system was put into effect, the number of anglers was far more evenly distributed over the entire fishing season. While fisherman days have increased each year, there has been appreciably

less crowding the first day on each stream. Fishermen know that if a definite number of days are listed to be fished, the streams indicated will be open on those days. Also, they know that each stream when opened will first have been rested from fishing for at least a few days and possibly much more. As nearly as is humanly possible, each fishing day becomes "an opening day."

The North Carolina trout season extends from about the middle of April to the end of August, which gives about 19 weekends of fishing, with a few special days extra. Since the weekends include Friday, this means that during 1941, for example, 64 fishing days were made available to the fishermen of the experimental area. Thirteen was the largest number of fishing days for any one stream. The lowest number was three, for a small isolated watershed, that could not be conveniently combined, administratively, with any other. However, so small a number of open days for a one stream proved to be unsatisfactory, or, at least, inefficient.

The "Pisgah System" may be modified to meet special conditions. An example of such a modification is a system of open fishing days for the experimental area being considered by the U. S. Forest Service and the North Carolina Conservation Commission for the duration of the war, to meet the abnormal restrictions which anglers must face in transportation to and from fishing waters. To change the distance to different streams is obviously impossible. To fish a stream more than its proportionate number of times in a season is against the principle of the Pisgah System, but gasoline and tires must be conserved and also fishermen want the relaxation of their sport to relieve their minds from the strains of war. Consequently, it is proposed to permit a disproportionally large amount of fishing in the watershed nearest to the majority of the anglers of the neighborhood. This is the Davidson. For 1943 the plan calls for approximately the 1941 and 1942 schedule of days for all streams in the experimental area except the Davidson. These streams will have their fishing days scattered as heretofore and will always have several days of rest after each opening day. But the Davidson River will be opened on all days when the others are closed. This gives the Davidson more open days than all the others combined. It is understood that fishing will be less satisfactory for the season as a whole, but it does permit the desired recreation on the most attractive Pisgah streams. It is expected that the average angler will spend most of the days he can spare for fishing during the season on the Davidson, with a couple or so days on one of the others. A large preseason plant and a series of sustaining plants later should provide fair fishing most of the season.

Recommendations

Where nothing is accurately known about the production of a stream, the logical beginning in a program of stocking is the planting table for trout streams (Davis, 1938). Where the production of a

stream is known, as determined accurately by a creel census, or estimated by other less accurate checks, it is recommended that this information be made the basis of the stocking program.

Also, since overstocking is the great danger that threatens all efforts to build up fishing by the planting of hatchery reared fish, it is believed that stocking with legal-size trout will give the most satisfactory results. If legal-sized fish are planted in the spring, there will be less danger of overstocking, since the surplus fish will be caught quickly.

The above principles certainly apply to the Pisgah experimental area and it is believed to be equally applicable to most trout streams of the southern Appalachians. It should apply equally well elsewhere where recoveries of legal-sized hatchery fish run as high as shown in the experiments. Rearing fish to legal size involves an expense that must always be considered. Unless recoveries of such planted fish are high, it probably cannot be considered economical to maintain the high fishing intensity that the use of large trout presupposes. Information received regarding spring plantings of legal-sized trout in other trout management areas of the region indicate that recoveries have been in line with those in the experimental area, so it is recommended that the practice in question be made standard for the region.

In the experimental area, as has been shown, the recoveries of native or wild fish have remained remarkably constant throughout the period of experimentation. In the early experimental years, native trout made up a large part of the total catch and even during the last year, when fishing was most intense, native fish formed about one-third of all trout taken. Holloway (1941) stated that throughout the region "natural reproduction of brook and rainbow trout supports a considerable part of the fishing load." These native trout, particularly while they are undersize, are benefited in the long run by the spring plants of large fish, since there is no competition for food during the interval between fishing seasons with small hatchery reared fish. Even though the large trout planted just before and during the fishing season may, as Hazzard (1938) pointed out, bring about a temporary food shortage for the larger wild trout, until anglers remove the surplus, those organisms of primary interest to the smaller trout are still preyed upon only by the wild fish, since they are the only small trout present.

Owing to the excellent survival rate of spring-planted legal-size trout and the high degree of natural reproduction, the waters of the Southern Appalachians do not require as heavy plants as is the case where such conditions do not exist. The tentative figure is advanced of planting three legal-sized trout in the spring to every two fish (hatchery and wild) which enter the fisherman's creel the preceding season.

Because of wartime restrictions on travel, fishing intensity may decrease. In that event, plantings must be reduced. It must never be forgotten that the plantings made in the experimental area since 1939, in particular, produce a trout population well in excess of what the

streams can support. It is only by heavy fishing that trouble can be avoided. If fishing slackens, plants must be correspondingly lowered.

Should funds for rearing hatchery fish be cut off for the duration of the present war, it is urged that when the day comes to resume stocking, plantings made the first year do not exceed the limit for the present degree of fishing intensity, regardless of how severely the streams may appear to be depopulated. Also, this rate of restocking should not be exceeded until fishing intensity passes the present point. Rebuilding fishing in the streams should be undertaken slowly. It is particularly urged that no combination of planting and closing of streams be attempted. The danger of overstocking is too great.

Literature Cited

Burrows, Robert, Jr.
1935. A stream survey of the waters of the Pisgah National Forest. U. S. Bur. of Fish. (mimeographed)

Davis, H. S.
1938. Instructions for conducting stream and lake surveys. U. S. Bureau of Fisheries, Fishery Circular No. 26; 55 pp., illus.

Hazzard, Albert S. and Shetter, David S.
1939. Results from experimental plantings of legal-sized brook trout (*Salvelinus fontinalis*) and rainbow trout (*Salmo irideus*). Trans. Am. Fish. Soc., Vol. 68, 1938, pp. 196-208.

Holloway, Ancil D. and Chamberlain, Thomas K.
1942. Trout management and stocking results in the national forests of the southern Appalachians. Trans. Seventh N. A. Wildlife Conference, pp. 245-249.

A FISH POPULATION STUDY OF THIRD SISTER LAKE[1]

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Abstract

The fish population of Third Sister Lake was removed by angling, netting and poison (rotenone). Fish were recovered after poisoning by intensive hand picking. An unknown number of fish, particularly those of the smaller sizes, did not come to the surface when killed by the poison and were therefore not recovered or included in the population analysis. A total of 15,454 fish weighing 866.6 pounds was recovered from all operations or 86.6 pounds per acre. Bluegills of legal length accounted for about 50 pounds per acre. Legal game fish made up approximately 70 per cent of the total weight of all fish.

In 80 man-hours of hook and line fishing during the 22 days prior to poisoning, 431 fish weighing 153 pounds were captured. Approximately one fourth of the total number of legal largemouth bass and bluegills in the lake were removed by this angling effort which equaled 4.6 fish per hour. Coarse fish made up 16.3 per cent and forage fish 3.4 per cent of the weight of all fish.

Introduction

The complete removal of fish from Third Sister Lake was not carried out for the primary purpose of making a fish population analysis but rather as part of a general investigation on the existing relationship between the fish and fish-food organisms in this lake. The study has now been in progress for 3 full years and may be continued through the next 2 or 3 years.

The destruction of the fish population was accomplished by means of rotenone (Derris root) which was supplemented by netting and angling during the 3 weeks previous to poisoning. The actual poisoning process and its effect on the fish and other organisms found in the lake is described by the authors elsewhere in this volume.

The first poisoning operation was carried out on May 6, 1941, before the spawning season and before the aquatic vegetation was extensive enough to hamper the recovery of fish. Test nets were set in the lake about the middle of May in order to determine if live fish were still present in the lake. On May 14 and during the ensuing 3 days, 4 large bluegills and one pumpkinseed sunfish were captured. Large schools of bluegill and pumpkinseed fry began to appear about the middle of July. Because the first poisoning did not kill all the fish, a second application was made on August 18 and 19 when water temperatures were more favorable. Only a very few adult fish were recovered along with many thousand bluegill and pumpkinseed fry. These were not included in the population total. After that time, however, no fish were seen in the lake until June, 1942, when a few long-eared sunfish

[1]Contribution from the Michigan Institute for Fisheries Research.

entered the lake, presumably via the outlet during high water. We believe that the poisoning was 100 per cent effective in the removal of fish in August.

The fish killed by poison were recovered by intensive hand picking which was persistently repeated until no fish could be found. No information is available concerning the efficiency of this method but confidence is expressed that a very great percentage of fish which came to the surface or could be seen from the surface were recovered. On the other hand evidence was found that not all dead fish float. This is particularly true of small specimens, and large numbers may never come within reach of the picker, which has been noted in earlier poisoning work by other Institute staff members. Careful research will show a considerable number of fish never are recovered, even under the most favorable conditions. In presenting these data, it is recognized that the recovered fish population is probably considerably less than the actual population and that the recovery of the different species and sizes within species may not be proportional to their actual abundance. Minnows, darters and the young of game fishes are, because of their size, missed more often than larger specimens. However, we believe the figures on total poundage are not seriously affected by this loss.

All of the fish were measured and weighed at the time of their recovery. Scale samples were saved from the various sizes of bass, bluegills and pumpkinseeds, and age was determined by examining the scales for annuli in the usual manner. Since collections were made approximately at the spawning season, an annulus was counted on the edge of all scales.

Many of the age determinations may not be reliable. Annuli interpretations, particularly in older fish, varied considerably with the interpreter. The oldest age group assigned for each species includes all fish which were considered to be of that age or older.

Game fish not actually aged were arbitrarily assigned to age groups representative of their size.

Third Sister Lake has a surface area of about 10 acres and a maximum depth of 55 feet. Approximately 35 per cent of the lake bottom is shallow enough to produce higher aquatic plants. This zone sustains predominantly yellow water lilies and pondweeds. Fish find abundant shelter and food in these plant beds and the lake compares favorably with the more productive small lakes of southern Michigan. The following species of fish were present before poisoning: Largemouth black bass (*Huro salmoides*), bluegill sunfish (*Lepomis macrochirus*), pumpkinseed sunfish (*Lepomis gibbosus*), green sunfish (*Lepomis cyanellus*), hybrid sunfish, bullheads (*Ameiurus natalis*), common suckers (*Catostomus commersonnii*), chub-suckers (*Erimyzon sucetta*), mud pickerel (*Esox vermiculatus*), black-chinned shiner (*Notropis heterodon*), black-nosed shiner (*Notropis heterolepis*), common shiner (*Notropis cornutus*), golden shiner (*Notemigonus crysoleucas*), mud minnow (*Umbra limi*), and Iowa darter (*Poecilichthys exilis*).

Fishing has been banned on this lake for the past 9 years. A number of fish were removed for stomach analyses during the 2 years (April 1, 1939-April 14, 1941) previous to poisoning. These included the following: 30 largemouth bass (19.4 pounds), 628 bluegill sunfish (148 pounds), 15 pumpkinseed sunfish, (2.6 pounds), 4 green sunfish (0.6 pound), 18 common shiner (3.0 pounds), 2 mud pike (0.1 pound), 2 bluegill-pumpkinseed hybrids (0.3 pound). This represents a total of 699 fish weighing 174.3 pounds. In addition to these, there was very probably a small number removed by poachers. All fish taken during the ice-free period of 1941, regardless of the method or purpose for which they were used, are included in the population figures. It is assumed that those taken earlier were probably compensated for in weight if not in numbers by the time of complete removal. It is believed that the fish population represents approximately the maximum carrying capacity for the lake.

Analysis of Fish Population

Largemouth black bass.—This species was the second most important game fish present in the lake on the basis of total weight. A total of 470 specimens weighing 126.9 pounds made up 3.04 per cent of the total number and 14.64 per cent of the total weight of all fish recovered. A summary of the bass by age groups is given in Table 1.

As might be expected, the largest number (49.1 per cent) of largemouth black bass were in age-group I. Age-group II was more poorly represented than was expected, with only 4.3 per cent of the total number. Age-group III was strong, with almost half as many fish as the age-group I, or 21.3 per cent of the total. Likewise, age-group IV was well represented with 18.1 per cent of the total number. Thompson and Bennett (1939) found the third and fourth year groups to be weaker in Lincoln Lakes, Illinois, than the fifth and sixth, while Eschmeyer (1938) reports that the first and fourth summer largemouth black bass were more numerous in Howe Lake, Michigan, than bass of other ages. Exactly 100 legal bass were collected from Third Sister Lake constituting 21.28 per cent of the total number of bass found. These weighed 96.08 pounds, or 75.71 per cent of all bass taken. Age-groups III, IV, V, and VI made up 88.6 per cent of the total weight of all bass. Of these, age-group IV made up 39.6 per cent. Third Sister Lake bass reached legal length (10 inches) late in their third or early in their fourth year.

Bluegills.—The bluegill was by far the most abundant game fish in the lake. A total of 4,057 specimens weighing 537.3 pounds made up 26.25 per cent of the total number and 61.99 per cent of the total weight of all fish recovered. A summary of the bluegills by age groups is given in Table 2.

Age-group VI was strong, contributing 8.9 per cent of the total number and 22.5 per cent of the total weight of the entire bluegill population. There were 1,560 legal bluegills, constituting 38 per cent of all

Table 1.—The age, size, number and weight of largemouth black bass recovered from Third Sister Lake

Age group	Number of specimens aged	Size range total length (inches)	Average total length (inches)	Number	Per cent of total number	Average weight (ounces)	Total weight (pounds)	Per cent of total weight
I..............	124	2.1- 4.1	2.9	231	49.1	0.14	2.01	1.6
II..............	20	5.9- 7.0	6.5	20	4.3	1.82	2.28	1.8
III..............	85	[1]7.0-11.0	8.7	100	21.3	4.25	26.58	20.9
IV..............	68	[2]7.6-14.4	11.2	85	18.1	9.45	50.25	39.6
V..............	17	11.8-15.2	13.1	19	4.0	15.85	18.83	14.8
VI..............	11	14 0-17.1	14.9	11	2.3	24.57	16.87	13.3
VII and older	4	15.9-18.1	16.7	4	0.9	40.50	10.13	8.0
Grand total	....	....	....	470	....	....	126.90	....

[1]Six specimens were legal length.
[2]Five specimens were sub-legal length.

Table 2.—The age, size, number and weight of bluegills recovered from Third Sister Lake

Age group	Number of specimens aged	Size range total length (inches)	Average total length (inches)	Number	Per cent of total number	Average weight (ounces)	Total weight (pounds)	Per cent of total weight
I..............	28	1.1-1.8	1.4	1,345	33.2	0.03	2.45	0.5
II..............	107	2.5-4.4	3.4	915	22.6	0.32	18.16	3.4
III..............	59	4.4-6.9	5.2	237	5.8	1.14	16.94	3.2
IV..............	72	4.7-7.3	6.5	280	6.9	2.87	50.23	9.3
V..............	63	6.1-8.4	7.4	296	7.3	4.20	77.79	14.5
VI..............	68	6.8-8.7	8.0	360	8.9	5.38	120.97	22.5
VII..............	63	7.6-9.0	8.3	270	6.7	5.99	101.00	18.8
VIII..............	49	6.6-9.1	8.6	166	4.1	6.46	66.99	12.5
IX..............	17	8.2-9.3	8.7	108	2.7	6.79	45.85	8.5
X and older	4	8.1-9.6	9.0	80	2.0	7.39	36.93	6.9
Grand total	....	....	....	4.057	....	....	537.30	....

Table 3.—The age, size, number and weight of pumpkinseeds recovered from Third Sister Lake

Age group	Number of specimens aged	Size range total length (inches)	Average total length (inches)	Number	Per cent of total number	Average weight (ounces)	Total weight (pounds)	Per cent of total weight
I..............	19	1.7-2.3	2.0	406	66.55	0.05	1 38	4.73
II..............	39	3.0-4.4	3.9	145	23.77	0.82	7.41	25.40
III and o'de	34	4.1-8.4	6.4	59	9.67	5.53	20.39	69.87
Grand total	....	....	....	610	....	....	29.18	....

bluegills recovered. These weighed 499.76 pounds, or 93.01 per cent of the total weight.

Like the largemouth black bass, most of the Third Sister Lake bluegills reached legal length late in their third or early in their fourth growing season.

Pumpkinseed sunfish.—Only 610 pumpkinseed sunfish were recovered from the lake. These weighed 29.18 pounds, or 3.37 per cent of the total weight of all fish. A summary of pumpkinseed population by age groups is given in Table 3.

All of the fish with three or more annuli were lumped into one group because we could not separate these older fish into age groups with any degree of certainty. There were 32 fish of legal length recovered which weighed 11.68 pounds, or 40.03 per cent of the entire pumpkinseed population. Most of the pumpkinseeds probably reach legal length (6 inches) in their third or fourth year of life.

Green sunfish.—A total of 96 green sunfish was recovered from the lake. These weighed 5.4 pounds and made up 0.62 per cent of the total weight of all fish in the lake. Only 5 of these fish had attained a length of 6 inches or longer.

Hybrid sunfish.—Thirteen hybrid sunfish were found. Five of these were pumpkinseed x bluegill and 8 were pumpkinseed x green sunfish. They had a total weight of 2.2 pounds and made up 0.25 per cent of the total weight of the entire fish population.

Bullheads.—The yellow bullhead was the second most abundant coarse fish found in Third Sister Lake. A total of 670 specimens were recovered, constituting 4.34 per cent of the total number of all fish. These had a weight of 88.1 pounds, or 10.16 per cent of the total weight of the entire fish population.

It was possible on the basis of size distribution to divide the bullhead population into 3 groups (Table 4). The first group, with an average total length of 2.1 undoubtedly represents age-group I. This group includes 61.3 per cent of the total number of all bullheads recovered. Likewise, we believe the second group, with an average total length of 4.9 inches, represents age-group II and this includes about 9 per cent of the total bullhead population. Those in the third group include fish three years and older and make up 29.7 per cent of the number and 91.4 per cent of the weight of all bullheads.

Common sucker.—Only 10 common suckers having a combined

Table 4.—The size, number, and weight of yellow bullheads recovered from Third Sister Lake

Size range (inches)	Average total length (inches)[1]	Number	Per cent of total number	Average weight (ounces)	Weight (pounds)	Per cent of total weight (pounds)
1.2 2.6	2.1	411	61.34	0.06	1.60	1.82
3.5-5.9	4.9	60	8.96	0.89	3.32	3.77
6.0-and over	9.3	199	29.70	6.69	83.16	91.44
Grand total	....	670	....	....	88.08	....

[1]Approximate lengths.

weight of 22.8 pounds were recovered. It is evident that this species was not reproducing in the lake and that its presence was due either to migration or introduction. All of the specimens were either 3 or 4 years old. It is entirely possible that these fish found their way up through the intermittent outlet during some previous high water period. Conditions in Third Sister Lake are apparently not suited for the natural reproduction of this species and the common shiner described below.

Chub-sucker.—The chub-sucker was the most common coarse fish in the lake. We recovered 947 specimens constituting 6.13 per cent of the total number of all fish in the lake. These weighed 16.6 pounds, or 1.92 per cent of the total weight of all fish recovered.

It was possible to separate the yearlings of this species from adults by their length frequencies. One-year-old specimens had a size range of 1.6-3.1 inches in total length (average 2.3 inches) while the adults ranged from 3.4-7.9 inches total length (average 5.1 inches). There was a total of 835 young as compared to 112 adult individuals. The combined weight of the age-group I fish was 4.28 pounds while that of the adults was 12.32 pounds.

Mud pickerel.—A total of 138 mud pickerel with a combined weight of 8.7 pounds was recovered from Third Sister Lake. These made up 0.89 per cent of the total number and 1.0 per cent of the total weight of the entire fish population.

It was not possible to determine the ages of these fish or divide them into groups on the basis of size. They ranged from 4.6-11.0 inches in total length (average 6.1 inches).

Black-chinned shiner.—The black-chinned shiner and black-nosed shiner made up slightly more than 50 per cent of the total number of fish recovered in this study. There was a total of 3,215 of the black-chinned shiners constituting 20.8 per cent of the total number of all fish recovered. These weighed 6.6 pounds or 0.76 per cent of the total weight of the entire fish population.

They had a size range of 1.1-2.4 inches in total length (average 1.9 inches).

Black-nosed shiner.—The black-nosed shiner was the most abundant fish in Third Sister Lake, represented by 4,530 specimens constituting 29.31 per cent of all fish. This species had a weight of 8.3 pounds, or 0.96 per cent of the combined weight of all fish. Their size ranged from 1.5-2.5 inches in total length with an average of 1.7 inches.

Common shiner.—All of the 30 specimens of common shiner recovered were adults. As mentioned above, this species and the common sucker probably do not reproduce successfully in Third Sister Lake. The specimens recovered ranged in total length from 5.3-8.4 inches (average 7.6 inches).

Golden Shiner.—Golden shiners, 174 in number, with a size range of 2.1-6.9 inches in total length (average 5.1 inches) were recovered. These made up 1.13 per cent of all fish collected. The combined weight

of this fish population was 5.9 pounds, or 0.68 per cent of the total weight of all fish collected. Both young and adult specimens were found but no attempt has been made to separate them.

Mud minnow.—The mud minnows recovered total 230 specimens or 1.49 per cent of the entire fish population. They weighed only 1.8 pounds, or 0.2 per cent of the total weight and ranged in size from 1.6-4.5 inches (average 2.8 inches).

Iowa darter.—A total of 264 darters weighing 0.3 pound were collected. This constitutes 1.71 per cent of the number and 0.04 per cent of the weight of all fish recovered. The darters ranged in size from 1.0-1.8 inches in total length (average 1.6 inches). The darters were the most inconspicuous and the least apt to float of any of the fish in the lake. We are sure that these figures are not representative of the actual population of this species.

Discussion

There was a total of 15,454 fish weighing 866.6 pounds recovered from Third Sister Lake (Table 5). These do not include the two largemouth bass, 17 bluegills, one pumpkinseed, one mud minnow, and one common shiner recovered either immediately before or after the second poisoning.

Third Sister Lake had a population of 86.7 pounds (1,545 fish) per acre. On the basis of existing fish population studies in North America, this production is intermediate between the northern natural lakes (Canada and Northern Michigan) and the southern artificial lakes (Illinois, Alabama, and Louisiana). It much more nearly approaches the northern averages, however. Meehean (1942), on the other hand, reported a range of 22-110 pounds per acre for 5 natural lakes in north central Florida. A comparison between the pounds per acre of the various waters studied does not have much significance unless the various factors contributing to lake productivity are considered. Natural lakes are more apt to be less productive than small artificial ponds because of their deeper basins and limited shallow water, regardless of whether they are situated in the north or the south. Three Nova Scotian lakes studied by Smith (1938) had an average of 24.3 pounds (977 fish) per acre while 6 Michigan lakes located in the upper part of the Lower Peninsula (Eschmeyer, 1938) had an average of 58.3 pounds (785 fish) per acre. Except for one lake (Standard) the average pounds per acre on these Michigan lakes was very close to that of the Nova Scotian lakes. Two Illinois lakes (Thompson and Bennett, 1939 A and B; Bennett, Thompson and Parr, 1940) had an exceedingly high production (average 439 pounds; 2,888 fish per acre). These artificial lakes are small, shallow and in general of a highly productive nature.

Two ponds situated in the deep south showed even greater production. Swingle and Smith (1940) report that a one-acre Alabama pond contained 657 pounds per acre while Viosca (1936) found 860 pounds

of fish per acre in a small borrow pit in Louisiana. Tarzwell (1941), on the other hand, found only 219 pounds of fish per acre in a two-acre pond in Alabama, and Juday (1938) gives an estimate of 365 pounds of fish per acre in a Wisconsin lake, showing that locatoin alone does not determine the productivity.

Game fishes.—The game fishes, represented by largemouth black bass, bluegills, pumpkinseed sunfish, and hybrid sunfish made up 33.3 per cent of the total number and 80.3 per cent of the total weight of all fish. About 11 per cent of the number and 70 per cent of the weight of all fish recovered were legal game fish. Bluegills were by far the most important species, a total of 1,560 legal bluegills being recovered. These weighed almost 500 pounds or about 50 pounds per acre.

Table 5.—Summary of numbers, weights, and pounds per acre of all fish recovered from Third Sister Lake

Species[1]	Number	Per cent of total number	Weight (pounds)	Per cent of total weight (pounds)	Pounds per acre
GAME FISHES:					
Largemouth black bass	470	3.04	126.9	14.64	12.69
Bluegills	4,057	26.25	537.3	61.99	53.73
Pumpkinseed sunfish	610	4.07	29.2	3.37	2.92
Hybrid sunfish	13	0.08	2.2	0.25	0.22
COARSE FISHES:					
Green sunfish	96	0.62	5.4	0.62	0.54
Yellow bullhead	670	4.34	88.1	10.16	8 81
Common sucker	10	0.06	22.7	2.63	2.27
Chub-sucker	947	6.13	16.6	1.92	1.66
Mud pickerel	138	0.89	8.7	1.00	0.87
FORAGE FISHES:					
Black-chinned shiner	3,215	20.80	6.6	0.76	0.66
Black-nosed shiner	4,530	29.31	8.3	0.96	0.83
Common shiner	30	0.19	6.6	0.76	0.66
Golden shiner	174	1.13	5.9	0.68	0.59
Mud minnow	230	1.49	1.8	0.20	0 18
Iowa darter	264	1.71	0.3	0.04	0.03
Grand total	15,454	....	866.6	....	86.66

[1]The categories of game, coarse, and forage fishes are in accordance with the present legal classification in Michigan.

During the 22 days prior to poisoning (May 6, 1941), a record was made of the number and kinds of fish removed by angling along with the number of hours of effort. All fishing was done with either fly rod or casting rod, using artificial lures. Fishermen were allowed to fish where they chose on the lake and operations were fairly well dispersed over the submerged plant beds in the lake. As might be expeoted, certain spots were favored. Several of the fishermen might well qualify as experts but about an equal number were either beginners or of only average skill and experience. We do believe, however, that in general the fishermen participating in this experiment would show a somewhat better average than the general run of fishermen over the state.

A total of 431 fish weighing 153 pounds were caught on fly rods in 80 man-hours of fishing. Of these, 9 were largemouth black bass

(weight 3.97 pounds), 396 were bluegills (weight 126.5 pounds), and 11 were pumpkinseed sunfish (weight 2.8 pounds). One each of common shiner, bullhead and hybrid sunfish were also taken. A total of 22 largemouth bass weighing 19.04 pounds were caught with a casting rod in 5½ man-hours of fishing. The average catch per hour of all angling was 4.62 fish as compared to the 1 fish per hour average reported in the general creel census for Michigan. Bennett, Thompson and Parr (1939) report a catch of 4.37 fish per hour on Fork Lake, Illinois, but the fishing period was spread over a much longer time.

During the period covered by our experiment, 22 per cent by weight and 8.6 per cent by number of the entire fish population of Third Sister Lake was removed. The bluegills caught by hook and line constituted 24.4 per cent of the number and 25.1 per cent of the weight of all legal bluegills in the lake; the largemouth bass taken in this manner made up 31 per cent of the number and 23.9 per cent of the weight of all legal bass in the lake.

Coarse fish.—Green sunfish, yellow bullhead, common sucker, chubsucker, and mud pickerel are considered in the category of coarse fish. They made up 12 per cent of the number and 16.3 per cent of the weight of all fish. There was a total of 14.1 pounds of coarse fish per acre.

Forage fish.—The six species of forage fish (Table 5) constituted 54.6 per cent of the number and 3.4 per cent of the weight of all fish recovered. There was a total of 2.95 pounds of forage fish per acre.

The numerical ratio between game, coarse and forage fish in Third Sister Lake was approximately 3:1:5 respectively and the weight ratio between these three categories was 27:5:1.

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Literature Cited

Bennett, George W., David H. Thompson, and Sam A. Parr
1940. Lake management reports. 4. A second year of fisheries investigations at Fork Lake, 1939. Ill. Nat. Hist. Surv., Biol. Notes No. 14; 24 pp.

Eschmeyer, R. W.
1938. The significance of fish population studies in lake management. Trans. Third N. Am. Wildlife Conf., pp. 458-468.

JUDAY, C.
1938. Fish records for Lake Wingra. Trans. Wis. Acad. Sci., Arts, and Lett., Vol. 31, pp. 533-534.

SMITH, M. W.
1938. A preliminary account of the fish populations in certain Nova Scotian lakes. Trans. Am. Fish. Soc., 1937, Vol. 67, pp. 178-183.

SWINGLE, H. S., and E. V. SMITH
1940. Fish production in terrace-water ponds in Alabama. Trans. Am. Fish. Soc., 1939, Vol. 69, pp. 101-105.

TARZWELL, CLARENCE M.
1941. The fish population of a small pond in northern Alabama. Trans. Fifth N. Am. Wildlife Conf., pp. 245-251.

THOMPSON, DAVID H. and GEORGE W. BENNETT
1939a. Lake management reports. 2. Fork Lake near Mount Zion, Illinois. Ill. Nat. Hist. Surv., Biol. Notes No. 9; 14 pp.
1939b. Lake management reports. 3. Lincoln Lakes near Lincoln, Illinois. Ill. Nat. Hist. Surv., Biol. Notes No. 11; 24 pp.

Viosca, Percy, Jr.
1936. Statistics on the productivity of inland waters: The master key to better fish culture. Trans. Am. Fish. Soc., 1935, Vol. 65, pp. 350-358.

THE FISH POPULATION IN THREE SMALL LAKES IN NORTHERN WISCONSIN

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ABSTRACT

An analysis of the total fish populations in three northern Wisconsin lakes, as revealed by the use of a derris-root treatment, designed to eradicate an undesirable carp population, is presented. The lakes were all bass lakes that had become infested with carp. A concentration of 1.25 pounds of derris root (5 per cent rotenone) was used per acre-foot of water. Preliminary, intensive netting operations were conducted to test the efficiency of ½-inch-mesh (stretched measure) fyke nets in estimating fish populations. From 10.4 to 15.6 per cent of the total weight of the fish present and from 6.8 to 31.1 per cent of the total number of individuals were caught. The wide variation in the percentage of individuals taken was due to a difference in species composition in the three lakes.

Long Lake (27.1 acres), contained a "total standing crop" of 59,072 fish or 2,180 per surface acre. The total weight was 3,657 pounds (135 pounds per acre). East Twin Lake (13 acres) had a population of 20,159 fish (2,413.5 pounds or 186 pounds per acre). West Twin Lake (13.5 acres) gave a total population of 5,809 fish, with a total weight of 1,243.2 pounds (92 pounds per acre). The role of the various species of fish in the community is discussed.

The three lakes were restocked according to a fish-management plan which was formulated in an attempt to restore each lake to its original status as a black bass lake. One lake was restocked with largemouth black bass, bluegills and fathead minnows; another with smallmouth black bass, bluegills and crayfish; and the third with largemouth black bass and bluegills.

INTRODUCTION

During the past few years, in an attempt to gather basic ecological data for improving fishing, workers in fish management have shown an increased interest in the determination of the total fish population or "total standing crop" in lakes and streams. Such information is vitally necessary in any program of fish management. In many lakes, the population may be unbalanced to such an extent that complete removal of the population is necessary. This condition was found to exist in the three lakes upon which the present report is based. The lakes which are discussed are landlocked black bass lakes in which carp became established.

The species composition of undesirable fish populations of small inland lakes varies widely. Some populations may consist largely of rough fish such as carp (*Cyprinus carpio*), or of predators such as garfish (*Lepisosteus osseus oxyurus*) and dogfish (*Amia calva*), or they may be game or panfish, such as yellow perch (*Perca flavescens*), walleyed pike (*Stizostedion vitreum vitreum*), or northern pike (*Esox lucius*), which may be ecological "misfits," usually present as a result

of transplants. Carp in the northern lakes are very undesirable, in that they compete with more valuable species for food, are not fished for, and so change conditions that the numbers of game fish are markedly reduced. Perch are almost as objectionable, in that they usually are slow growing or stunted, compete for food, and may take such a heavy toll of game-fish fry and fingerlings that they soon dominate a lake. Black crappies (*Pomoxis nigro-maculatus*) likewise have overrun certain northern lakes into which they have been introduced.

Many methods have been tried in attempts to control undesirable fish populations. Because it is practically impossible to eliminate completely a fish population by means of seines and fyke nets, various chemical methods have been employed with varying success. The results of certain of these experiments will be reviewed briefly.

Titcomb (1914) was the first to use copper sulphate as a means of destroying a population of an undesirable species. Catt (1934) and Smith (1935, 1938, 1940) treated several Nova Scotia lakes with copper sulphate and studied the effects of the treatment on the fish population as well as other fauna and the flora. The copper sulphate failed to kill all of the fish. This method is further complicated by differences of species susceptibility, and by the effects of temperature, degree of hardness of the water, and other factors on the toxicity of the copper sulphate. In addition, copper sulphate destroys algae and other fish-food organisms. Eschmeyer (1937, 1938a, 1938b, 1938c) used powdered derris root (5 per cent rotenone) for the destruction of populations of stunted perch in several Michigan lakes. Derris root is much more effective than copper sulphate in killing fish. When properly administered, it will destroy all fish, and for this reason its use is restricted to the elimination of obnoxious fish or of fish in overpopulated bodies of water. The use of derris root has now been adopted by several States for the study of total productivity and for the removal of undesirable populations. When used properly the fish-food organisms are not destroyed (Leonard, 1939).

Derris root was used in three small lakes in Bayfield County, Wisconsin, in order to remove completely an undesirable carp population. At the same time, a study was made of the total fish population in the lakes. This study of complete fish populations is the first that has been made in Wisconsin. The three lakes treated are Long Lake, East Twin Lake, and West Twin Lake. In the discussion of results to follow, the data for the three lakes will be compared.

Description of the Lakes

Long Lake is located about 7 miles west of the town of Washburn, Bayfield county, Wisconsin, Sec. I, T. 48 N., R. 6 W., and Sec. 6, T. 48 N., R. 5 W. The lake has an area of 27.1 acres, a shoreline of 1.1 miles, an average depth of 10 feet, and a maximum depth of 15 feet. The shores and littoral region are sand and gravel, while the center is

clay, with a thin layer of muck. The surrounding country is wooded, with jack pine and highland brush.

West Twin Lake is located approximately 2 miles northwest of Long Lake. The lake has an area of 13.5 acres, an average depth of 20 feet, and a maximum depth of 35 feet. Much of the shore area is sand and gravel, while the balance is clay. The center of the lake is clay and muck. A good stand of jack pine surrounds the lake.

East Twin Lake is located a quarter-mile east of West Twin Lake. It has approximately the same size (area, 13 acres), is more or less round, with a maximum depth of 15 feet, and an average depth of 10 feet. There is a small amount of sand and gravel shore; however, most of the shore is clay and muck, while the bottom is clay with a covering of muck. The surrounding country is covered principally with jack pine.

History of Angling in the Lakes

The early history of the three lakes indicates that they were substantially bass lakes. Sixty years ago, Long and West Twin Lakes had a reputation of being probably the best smallmouth black bass (*Micropterus dolomieu dolomieu*) lakes in Bayfield county. East Twin Lake was primarily a largemouth black bass (*Huro salmoides*) lake. The fishing was excellent. In 1891, however, Dr. W. C. Coburn and Mr. George Francis, two enthusiastic sportsmen, planted a number of carp in the lakes in order to "make fishing better." The black bass fishing held up well for some years but about 1910 began to decline rapidly and by 1920 had become so poor that angling had been practically abandoned. The opinion locally was that the carp population was responsible for the decrease in bass. Since 1920, Long Lake has received a number of plantings of various species of fish. Near 1930, yellow perch were introduced and in 1937, Long Lake received 700 adult black crappies, while East and West Twin Lakes were each stocked with 150 black crappies. These lakes had never contained crappies before 1937. Fishing remained poor. Only occasional walleyed pike or crappies were taken. The bass fishing had entirely disappeared before the introduction of crappies and it should be noted that no bass whatsoever were taken in the nets or killed by the derris root in Long Lake. Only a few bass were taken from East Twin and West Twin Lakes.

The Problem of Restoring Angling

Since fishing had declined to such an extent that only an occasional crappie or walleyed pike could be taken, and very few people fished the lakes, the problem was presented of attempting to restore the lakes to their original status as black bass lakes. It was known that the lakes contained carp and other undesirable species which had undoubtedly so changed the environment that few, if any, black bass could exist. It was obviously necessary first to eliminate completely the undesirable

population and then restore the lakes by means of a scientific fish-management plan.

Now it is an accepted fact that each lake is an individual entity The various physical, chemical, and biological factors present give any lake a certain character which is reflected in the total crop or productivity of the lake in pounds of fish per acre. The productivity probably remains more or less constant unless some change occurs in the physical, chemical, and biological conditions. From the practical standpoint it is desirable that the population of these three Wisconsin lakes be composed of bass and bluegills instead of the undesirable carp, stunted perch, and other species. The total poundage of fish per acre would be the same for either population.

Procedure

It was thought desirable to harvest as many as possible of the more valuable species for transfer to more suitable waters before the poison was placed in the lakes. Fyke nets (5 feet deep with ½-inch mesh, stretched measure) were employed for the purpose. These nets were fished until the catch was so small as to make further netting impractical. Thirteen fyke nets were fished for 12 days in Long Lake, 16 nets for 5 days in West Twin Lake, and 19 nets for 3 days in East Twin Lake. All carp caught were killed, measured, weighed, and buried, while all other fish were counted, weighed, and measured, and then transferred to other lakes in the county.

The derris root (5 per cent rotenone content) was applied by several methods. A pumping unit powered with a gasoline motor was operated from a motorboat over the lake to spray a thin water suspension of derris on the surface. Motorboats, with a gunny sack, containing about 50 pounds of powdered derris root tied to each side, were run in a crisscross pattern so that the lake surface was uniformly treated. As the boats traveled over the lake, the ropes tied to the sacks were given an occasional tug with the result that a steady stream of derris flowed from under the boat. In addition, derris was mixed with water to make a thin suspension which was poured slowly from buckets over the bow of the boat propelled by an outboard motor. Finally the ordinary 5-gallon back-pack fire fighting pumps were used to spray the shallow shore areas.

Fish began to appear within 5 minutes after treatment started, and the number showing distress rapidly increased. Many of the fish floated and were picked up immediately. Collection of fish continued for 4 days. The greater portion of them were picked up on the second day, and by the fourth day, only an occasional straggler could be found. The rapidity of reaction varied in the lakes. In Long Lake, with a water temperature of 76° F., fish started coming to the surface within 5 minutes, while the fish were much slower in reacting to the poison in Twin Lakes, in which the water temperature was 59° F.

The dead fish were picked up and sorted according to species. Prac-

tically all fish collected on the first day were measured individually, and representative samples of scales were taken for growth study. The lake was cleared of fish daily after the first day, and all were sorted into species, counted, and weighed.

Long Lake was treated on August 11, 1941, with 340 pounds of derris root. The total cost of treatment was approximately $4.13 per surface acre. West Twin Lake was treated on September 10, 1941, with 310 pounds of derris root, while East Twin Lake received 200 pounds on the afternoon of the same day.

Population Statistics

Fish removed by netting.—The results of netting operations in each of the three lakes have been grouped together for comparison (Table 1). Although the lakes were netted intensively, the catch of carp was of little consequence. Of 4,000 fish taken from Long Lake, only 8 were carp. Two carp were caught in West Twin Lake and 30 in East Twin Lake. Each lake had a heterogeneous assortment of species for such small "bass" lakes. The principal species were yellow perch and black crappies with some walleyed pike. The total catch of fish as a result of intensive netting was: Long Lake—4,000 individuals with a weight of 566.5 pounds; West Twin Lake—1,779 individuals with a weight of 120 pounds; East Twin Lake—1,274 individuals with a weight of 345.5 pounds.

Fish removed by rotenone.—Table 1 also lists the total number, total weight, and average weight of fish destroyed by rotenone in the three lakes. Although yellow perch contributed the largest number of any species in Long Lake (34,856), the carp population accounted for the most pounds (2,009). A total of 55,072 fish, weighing 3,091 pounds was collected after the treatment. Of the total of 3,091 pounds, only 132 pounds consisted of game fish (walleyed pike and black crappies). The yellow perch can be classified only as "scrub" perch since their size ranged from 2½ to 4½ inches. During the netting operations, 504 common white suckers (*Catostomus commersonnii commersonnii*) were removed, while only 76 were destroyed by the chemical. In contrast to this situation 8 carp were taken by netting, while 1,958 were poisoned. The relative efficiencies of the two methods of fish removal, exhaustive netting and derris root, are given in Table 1. Extensive fishing with nets until the daily catch was so small as to make further work impractical resulted in the removal of only 6.8 per cent of the total fish population (by number) of Long Lake. Furthermore, this method failed to remove many of the carp. Of the total poundage of fish in the lake, netting removed 15.6 per cent. The application of derris root accounted for the balance of the population (93.2 per cent of the total number of fish and 84.4 per cent of the total pounds) originally present in the lake.

The total standing crop in Long Lake (sum of netted and poisoned fish) consisted of 59,072 individuals or 2,180 fish per acre. The ex-

Table 1.—Number and weight of fish removed from Long, East Twin, and West Twin Lakes by netting and poisoning

Species[1]	By netting			By poisoning			Grand total	
	Number	Weight (pounds)	Average weight per fish	Number	Weight (pounds)	Average weight per fish	Number	Weight
Long Lake								
Walleyed pike (ad.)	20	53	2.65	18	42	2.33	38	95
Walleyed pike (fgl.)	....	....	......	1,750	6	0.01	1,750	6
Black crappie (ad.)	....	....	......	414	90	0.21	414	90
Black crappie (fgl.)	791	113	0.14	16,000	32	0.01	16,791	145
Yellow perch	2,676	69	0.02	34,856	868	0.02	37,532	937
Common sucker	504	324	0.64	76	44	0.57	580	368
Carp	8	7	0.87	1,958	2,009	1.02	1,966	2,016
Bluegill	1	0.5	0.50	......	......	......	1	0.5
Total	4,000	566.5	......	55,072	3,091	......	59,072	3,657.5
Percentage of total number	6.8	......	......	93.2	......	......	......	......
Percentage of total weight	....	15.6	......	......	84.4	......	......	......
East Twin Lake								
Black crappie (ad.)	1,121	300	0.26	240	51	0.21	1,361	351
Black crappie (fgl.)	100	0.5	0.01	14,265	95	0.01	14,365	95.5
Carp	30	26	0.86	2,632	1,868	0.71	2,662	1,894
Largemouth bass (ad.)	1	0.5	0.50	7	9.5	1.36	8	10
Largemouth bass (fgl.)	1	0.25	0.25	1,732	35	0.02	1,733	35.25
Walleyed pike	21	18	0.86	9	9	1 03	30	27
Total	1,274	345.25	......	18,885	2,068.5	......	20,159	2,413.75
Percentage of total number	6.4	......	......	93.6	......	......	......	......
Percentage of total weight	....	14.3	......	......	85.7	......	......	......
West Twin Lake								
Carp	2	2	1.00	970	1,002	1.03	972	1,004
Smallmouth bass (ad.)	....	......	......	8	15.5	1.94	8	15.5
Smallmouth bass (fgl.)	302	10	0.03	310	12.5	0.04	612	22.5
Yellow perch (ad.)	220	37	0.17	231	33	0.14	451	70
Yellow perch (fgl.)	977	20	0.02	367	17.5	0.05	1,344	37.5
Black crappie (ad.)	196	49	0.25	67	15.25	0.23	263	64.25
Black crappie (fgl.)	78	0.5	0.01	848	5.25	0.01	926	5.75
Bluegill (ad.)	....	......	......	14	5	0.36	14	5
Bluegill (fgl.)	2	0.5	0.25	1,215	17	0.02	1,217	17.5
Common sucker	2	1	0.50	......	......	......	2	1
Total	1,779	120	......	4,030	1,123	......	5,809	1,243.0
Percentage of total number	31.1	......	......	68.9	......	......	......	......
Percentage of total weight	....	10.4	......	......	89.6	......	......	......

[1]Ad. = adult; fgl. = fingerling.

tremely large number of runt perch and the "knot-head" condition of the carp indicated overcrowding and stunting. The "knot-head" condition of carp and the causes contributing to it were discussed by Thompson (1928). In recent years, since the stocking of perch, the lake has been fished very little. It contained very few game fish of a desirable size from the standpoint of angling.

The total standing fish crop was large, 3,657.5 pounds or approximately 135 pounds per acre. This "productivity" exceeds those found by Catt (1934) and Smith (1935, 1938, 1940) for the Nova Scotia lakes (17.0 to 36.0 pounds per acre) and also most of those found by Eschmeyer (1937, 1938a, 1938b, 1938c) for the Michigan lakes and ponds (five lakes with 21.0 to 49.0 pounds per acre and one lake with 194.0 pounds per acre). However, Thompson and Bennett (1939) found higher values for Illinois lakes and ponds (232.0 to 1,143.0 pounds per acre). Furthermore, certain Alabama ponds, Tarzwell (1940) (219.0 pounds per acre) and the Louisiana ponds, Viosca (1935) (860.0 pounds per acre), all contained greater weights of fish than Long Lake, due to a number of factors, of which higher fertility of the water and longer feeding seasons are perhaps the most important.

Calculations were made for each important species, of the percentage of the total population in each size group (Table 2).

The length-frequency distribution supported the belief that conditions within the lake were abnormal. All of the carp were in a starved, "knot-head" condition and none were found that were less than 11 inches long. Since the carnivorous varieties were increased considerably within the last 5 years (addition of crappies), it is quite possible that the young-of-the-year carp are destroyed by predators, since with such a large population of carp, it is unreasonable to suppose that no reproduction occurred. The same situation occurred with the common sucker. With the walleyed pike, only large fish and young of the year were found. Only a comparatively few large walleyed pike were present in the lake. The presence of the young of the year indicates that spawning occurred since no fry had been planted. However, no walleyed pike were taken whose size fell between that of the current season's young and fish 17 inches long. All small fish, of the various

Table 2.—Calculated percentage of total population of Long Lake in each size group

Carp		Black crappie		Common Sucker		Walleyed pike	
Total length (inches)	Percentage	Total length (inches)	Percentage	Total length (inches)	Percentage	Total length (inches)	Percentage
11-12	1.5	2-4	92.1	8-10	22.3	2-3	96.2
12-13	22.8	4-6	5.0	10-12	40.7	17-21	3.8
13-14	46.9	6-8	1.5	12-14	37.0	....	....
14-15	19.1	8-10	1.0	....	....	....	....
15-16	5.0	10-12	0.4	....	....	....	....
16-17	2.7	....	....	....	....	....	....
17-18	0.9	....	....	....	....	....	....
18-25	1.2	....	....	....	....	....	....

species present, were collected in the shoal area in less than 1 foot of water. The bottom could be seen clearly, even when covered with several feet of water, and no small fish were observed in these deeper areas. The only fish which seems to have been holding its own was the dominant black crappie. In this species, all size groups were taken from 2 to 12 inches. The examination of scale samples from the smaller carp and suckers, and from the adult walleyed pike, revealed that they were all 6 years old or older.

A total of 4,030 fish of all species with a weight of 1,123 pounds, were removed by the use of derris root in West Twin Lake. Of these, 970 fish were carp weighing 1,002 pounds (average weight of slightly over 1 pound). The total fish population, including netted and poisoned fish, consisted of 5,809 individuals having a total weight of 1,243 pounds. The total production therefore, was 92 pounds of fish per acre.

Carp made up 1,002 pounds or 80.6 per cent of the total of 1,243 pounds. The derris killed 68.9 per cent of all the fish originally present or 89.6 per cent of the total pounds of fish. The fyke nets removed 31.1 per cent of the population but only 10.4 per cent of the total weight.

The total number of fish, of all species in East Twin Lake, killed by the derris root was 18,885 which had a weight of 2,068 pounds. The total standing crop of the lake (fish netted or poisoned) amounted to 20,159 fish with a weight of 2,413.5 pounds. The standing crop amounted to 1,551 individuals or 186 pounds of fish per acre. This production agrees quite well with that of Long Lake. Of the 2,413.5 pounds of fish in the lake, 1,868 pounds or 77.4 per cent consisted of carp. The more desirable fish weighed only 545.8 pounds.

In the netting operations, 6.4 per cent of the total number of fish and 14.3 per cent of the total weight were removed. The derris root accounted for the balance or 93.6 per cent by number and 85.7 per cent by weight. Here as in the other lakes few carp were taken by nets.

Recommendations for Future Management

As a result of the present study, the approximate total potential productivity in pounds of fish per acre is known for each of the three lakes. The productivity (standing crop) of 135 pounds per acre for Long Lake, 92 pounds per acre for West Twin Lake, and 186 pounds per acre for East Twin Lake should be considered as minimum. With the removal of the carp, the remnants of weed beds should multiply and spread with a resulting increase in insect larvae or other available food.

The fish-management programs recommended for the three lakes are as follows: Long Lake—stock the lake with 2,000 smallmouth black bass fingerlings, 500 adult bluegills (*Lepomis macrochirus macrochirus*) and 13,000 fathead minnows (*Pimephales promelas*). This stock should be allowed to build itself up to the full carrying capacity of 135

pounds per acre. West Twin Lake—stock the lake with 1,500 smallmouth black bass fingerlings, 350 adult bluegills and in addition, plant 2,000 crayfish. No additional plantings of any kind are to be made. East Twin Lake—stock the lake with 1,500 largemouth black bass fingerlings and 300 adult bluegills. No additional fish whatsoever are to be planted.

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Drs. Ralph Hile, John Van Oosten, and Edward Schneberger, read the manuscript and offered criticisms and suggestions for presenting the data.

Summary

1. Three lakes in Bayfield County, Wisconsin, whose size ranged from 13 to 27.1 acres, were fished with fyke nets for 3 to 12 days, and then treated with derris root which destroyed the total remaining population.

2. Netting removed from 6.4 per cent to 31.1 per cent of the total numbers and from 10.4 per cent to 15.6 per cent of the total weight.

3. The effectiveness of the nets varied widely according to the species. Carp in particular were relatively scarce in the catch.

4. The total numbers of fish in the different lakes were: Long Lake—59,072; East Twin Lake—20,159; West Twin Lake—5,809. The total weights were: Long Lake—3,657.5 pounds; East Twin Lake—2,413 pounds; West Twin Lake—1,243 pounds.

5. The numbers of fish per acre were: Long Lake—2,180; East Twin Lake—1,551; West Twin Lake—430. The total weights per acre were: Long Lake—135 pounds; East Twin Lake—186 pounds; West Twin Lake—92 pounds.

6. The black crappie was the only species in Long Lake having a normal distribution of age groups. Only large individuals of carp and suckers were found. Large walleyed pike and young of the year were present but fish of intermediate sizes were absent. The black crappie was very probably "ecologically dominant" although the carp made up 55.1 per cent of the total weight.

7. Situations in East Twin Lake and West Twin Lake were similar to that encountered in Long Lake. Apparently the black crappie was dominant in these lakes also, although the carp made up the bulk of the total weight of the populations (East Twin Lake—77.4 per cent; West Twin Lake—80.6 per cent).

8. The condition of all three lakes was such that the complete eradication of the population was eminently desirable, as, with the exception of black crappies, almost no game fish of suitable size for capture by anglers were present in these formerly highly reputed black bass lakes.

9. A management program has been instituted whereby it is hoped the three lakes will be restored to their former status as excellent black bass waters.

Literature Cited

Catt, James
1934. Copper sulphate in the elimination of course fish. Trans. Am. Fish. Soc., Vol. 64, pp. 276-279.

Eschmeyer, R. W.
1937. Some characteristics of a population of stunted perch. Pap. Mich. Acad. Sci., Arts and Let., Vol. 22 (1936), pp. 613-628.
1938a. Experimental management of a group of small Michigan lakes. Trans. Am. Fish. Soc., Vol. 67, (1937) pp. 120-129.
1938b. Further studies of perch populations. Pap. Mich. Acad. Sci., Arts and Let., Vol. 23 (1937), pp. 611-631.
1938c. The significance of fish population studies in lake management. Trans. Third N. Am. Wildlife Conf., pp. 458-468.

Leonard, J. W.
1939. Notes on the use of derris as a fish poison. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 269-279.

Smith, M. W.
1935. The use of copper sulphate for eradicating the predatory fish population of a lake. Trans. Am. Fish. Soc., Vol. 65, pp. 101-113.
1938. A preliminary account of the fish populations of certain Nova Scotian lakes. Trans. Am. Fish. Soc., Vol. 67 (1937), pp. 178-183.
1940. Copper sulphate and rotenone as fish poisons. Trans. Am. Fish. Soc., Vol. 69 (1939), pp. 141-157.

Tarzwell, Clarence M.
1940. The fish population of a small pond in northern Alabama. Trans. Fifth N. Am. Wildlife Conf., pp. 245-251.

Thompson, David H.
1928. The "knothead" carp of the Illinois river, Ill. Nat. Hist. Survey Bull., Vol. 17, Art. 8, pp. 285-320.

Thompson, David H., and George H. Bennett
1939. Lake Management reports. 2. Fork Lake near Mount Zion, Illinois. Biol. Notes No. 9, Ill. Nat. Hist. Survey, pp. 1-14.
1939. Fish management in small artificial lakes. Trans. Fourth N. Am. Wildlife Conf., pp. 311-317.

Titcomb, J. W.
1914. The use of copper sulphate for the destruction of obnoxious fishes in ponds and lakes. Trans. Am. Fish. Soc., Vol. 44, pp. 20-24.

Viosca, Percy
1935. Statistics on the productivity of inland lakes: the master key to better fish culture. Trans. Am. Fish. Soc., Vol. 65, pp. 350-358.

SCYPHIDIA THOLIFORMIS, A PERITRICHOUS PROTOZOAN FOUND ON THE GILLS AND EXTERNAL SURFACES OF *MICROPTERUS DOLOMIEU* AND *MICROPTERUS SALMOIDES*

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ABSTRACT

Scyphidia tholiformis is an urn-shaped peritrichous protozoan measuring about 59 microns in length and 35 microns in width. It possesses a double row of cilia about one-third of the distance from the anterior end of the body and has a large scopula which is variable in shape and provides a large surface for attachment. The macronucleus is long and band-like, and makes a semicircle beneath the peristome from which it extends into the lower part of the body. The small, ovoid micronucleus is located near the middle of the body.

The organism is found on the external body surfaces and the gills of largemouth and smallmouth black bass. Its relationship to its host is probably that of an ecto-commensal, but there is further evidence that these organisms may indirectly cause mortality among bass.

The organism is interesting because of the manner in which it becomes dome-shaped when it leaves its host, causing it to resemble *Trichodina*. In this form, locomotion is accomplished by means of the central cilia.

It reproduces by longitudinal binary fission and cojugation of anisogametes.

INTRODUCTION

In October, 1939, another undescribed species of *Scyphidia* appeared in large numbers on the gills and external surfaces of largemouth and smallmouth black bass in the same warm-water circular pools at Leetown, West Virginia, in which *Scyphidia micropteri* (Surber, 1940) was found the previous year. At first, it seemed that this was merely a stage in the life cycle of *Scyphidia micropteri*. This was disproved after repeated observations (October 19, 1939 to August 4, 1940) and the organism was given the specific name *tholiformis* because of its characteristic dome shape during locomotion.

Scyphidia tholiformis is of particular interest because of its complicated methods of reproduction, as well as its ability to transform itself into a free-swimming, dome shaped, antero-posteriorly flattened ciliate, superficially resembling *Trichodina*, a parasite of trout and bass commonly found in hatcheries.

The first record of the new species at Leetown occurred in 1937. On September 10, 1937, Dr. James S. Gutsell examined some large fingerling smallmouth black bass which were being held for distribution in a concrete raceway 125 by 8 feet. These fish had begun to die in considerable numbers, and when they were examined, he recorded the presence of suctorians and a ciliate. His rough sketch of the latter

animal showed a band of central cilia, and, from its outline, it undoubtedly was the species described in this paper.

Scyphidia tholiformis was also found in abundance (August 3, 4, 1940) in concrete raceways at the New Jersey State Fish Hatchery at Hackettstown on largemouth bass fingerlings about 2 inches in length. Mr. Robert O. Hayford of the Hackettstown Hatchery states that large numbers of small bass are lost unless treated to remove this organism. He prescribes immersion of the fish for one hour in a 1.5 per cent salt solution. Although this organism has not caused any loss of fish at Leetown, its presence in large numbers must be regarded with suspicion.

Dr. H. S. Davis called the attention of the writer to this species during the course of his studies on the parasites of bass. He also loaned slides with sectioned gills of the channel catfish, *Ictalurus punctatus*, collected at Fairport, Iowa, July 14, 1916, possessing *Scyphidia* which proved to be *Scyphidia tholiformis*. The writer is indebted to Dr. Davis and to Mrs. Estelle Lazar, formerly of the staff of the Fisheries experimental Station, Leetown, West Virginia, for valuable aid as well as for living and stained material.

The writer expresses appreciation for generous cooperation extended by Robert O. Hayford and Charles O. Hayford during observations on this species at Hackettstown, New Jersey.

Identification

The genus *Scyphidia* includes a group of solitary peritrichous, ciliated protozoa belonging to the Family Vorticellidae and having the following characters: Body cylindrical or urn-shaped and without a stalk; adherent posteriorly to foreign bodies by means of an acetabuliform organ of attachment; surface of the integument often transversely or obliquely furrowed; body usually without cilia; oral end with a ciliary disc provided with two ciliary girdles running in a contraclockwise spiral; margin of the peristome padded, rarely turned down; peristomial groove continued as a vestibule, with the cytostome at its end; position of contractile vacuole variable; macronucleus of variable form.

The species described in this paper is a typical example of the genus. There are no described species of this genus (or closely related genera) which bear even a close structural resemblance to it. Only one species, *Scyphidia rhizopoda* (Lepsi) has been recorded with a band of central cilia. Grenfell (1887) observed cilia in the middle region of *Scyphidia amoebaea* during transverse fission. *Scyphidia annulata* (Edmondson) and *Scyphidia micropteri* Surber have a clear ring around the body located in the posterior and middle regions, respectively. In neither species does the ring bear cilia.

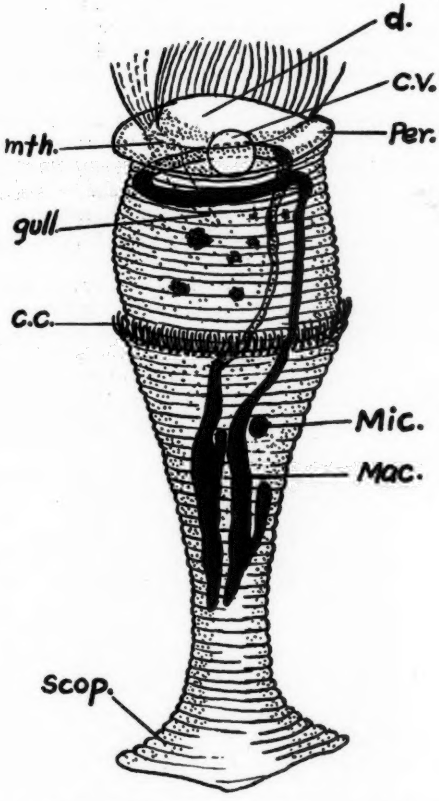

Figure 1.—Sketch of *Scyphidia tholiformis* showing structure (x about 1,980).

c.c.—central cilia
c.v.—contractile vacuole
d.—ciliary disc
gull.—gullet
mac.—macronucleus
mic.—micronucleus
mth.—mouth
per.—peristome
scop.—scopula

Description

Scyphidia tholiformis (N. S.) has the characteristic urn shape which is generically representative (Figures 1, 2(C), 3). The average length of thirty-three living specimens was 59.1 microns. (The maximum length was 82.9 microns, the minimum length 42.9 microns.) The average width (measured a short distance below the peristome) was 35.2 microns.

The entire body from scopula to peristome is annulated. A girdle consisting of a double band of cilia is located about one-third of the distance from the peristome to the base. The scopula is a wide-spreading, cup-like organ of attachment, variable in shape. Its average width in the above-mentioned group of living specimens was 34.8 microns. In two specimens, 57.1 and 68.6 microns in length, the scopula attained a maximum diameter of 48.6 microns.

The gullet is shorter than in *Scyphidia micropteri* and the contractile vacuole which is just below the ciliary disc, is located more anteriorly. The average diameter of the contractile vacuole is about 10.7 microns.

The macronucleus extends through most of the body as a paired, elongated structure (See Figures 1 and 4) and is joined anteriorly by a horseshoe-like semicircle about the peristome. In its usual semi-

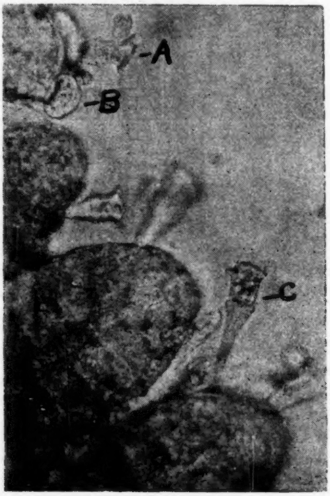

Figure 2.—Various forms of *Scyphidia tholiformis* on gills of *Micropterus dolomieu:* A—conjugating individual; B—Motile stage; C—normal vegetative animal (x about 338, from living material).

contracted position the macronucleus appears to be wider posteriorly, but in well-extended specimens, it can be seen to be of about equal width throughout. On the left arm of the macronucleus (with the mouth of the animal to the observer's left as in Figure 1), there is probably always a short "prong" to the macronucleus. It measures about 9.0 microns long and branches off about 10.0 microns from the posterior end of the macronucleus. Both arms of the macronucleus may bear these prongs, but the right arm is generally without it. The macronucleus is about 2.7 microns in width. In ten stained specimens which averaged 64.4 microns in length, the macronucleus averaged 39.1

Figure 3.—Living, unattached and well-extended specimen of normal vegetative stage (x about 723).

microns from the anterior to the posterior extremities. The posterior ends of the macronucleus are sometimes bent anteriorly or are twisted about each other (Figures 4 and 5).

The micronucleus is ovoid in shape (Figure 5), measures about 2.9 by 2.7 microns, and is located below the band of central cilia in the middle of the animal.

The animal changes from an urn-shaped to a discoidal or dome shaped form (Figure 2, B) when it leaves its attachment. At this time the peristome contracts, and the cilia about the peristome are folded in. The scopula is drawn into the body. After contraction, the band of central cilia becomes posteriorly located and is used for locomotion.

One individual which assumed this form measured 51.4 microns in diameter and 28.6 microns in depth.

Methods of Reproduction

Reproduction in *Scyphidia tholiformis* is by longitudinal fission and conjugation of anisogametes or heterogametes. In conjugation, microgametes are formed by exogenous budding or gemmation which apparently takes place very rapidly. Individuals in the process of gamete formation can be readily distinguished from those undergoing conjugation. During gamete formation, the macronuclear material is

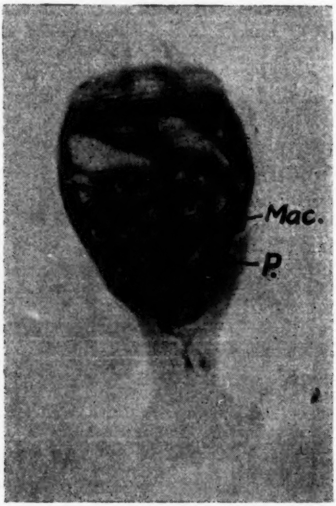

Figure 4.—Stained specimen showing macronucleus (Mac.) and macronuclear prong (P), (x about 1,087).

divided into a few (not more than eight) large, rounded bodies; the endoplasm remains unvacuolated; the exogenous bud (or microgamete) in the process of being cut off contains four large nuclear masses and apparently four small ones. In an individual destined to become the female or macrogamete the macronucleus divides into many (about thirty-two) large, irregularly shaped bodies. Macronuclear division begins at the posterior end and is preceded by micronuclear division. Female gametes in the process of conjugation usually have only one microgamete attached near the anterior end of the peristomial border (Figure 2, A). The microgametes (about 11.0 by 8.0 microns in size) at the time of conjugation apparently have eight large

Figure 5.—Stained specimen showing micronucleus (Mic.), (x about 796).

bodies of nuclear material within them. Conjugation evidently occurs at a much slower rate than gamete formation for large numbers of conjugating individuals can be found in material where it is taking place.

Attempts to define precisely the significance of the series of complicated divisions which the micronucleus, as well as the macronucleus, undergo in sexual reproduction have proved fruitless.

Asexual reproduction is accomplished by longitudinal fission, but relatively few dividing individuals were observed. In this method, the macronucleus becomes rounded and centrally located and is in close association with the micronucleus which is posterior to it. The constriction of the body and macronucleus occurs after the division of the micronucleus.

References

Surber, Eugene W.
1940. *Scyphidia micropteri*, a new protozoan parasite of largemouth and smallmouth black bass. Trans. Am. Fish. Soc., 1939, Vol. 69, pp. 169-175, 1 fig.

Grenfell, J. G.
1887. XI.—On new species of *Scyphidia* and *Dinophysis*. Journal, Royal Mic. Soc., pp. 558-560. London.

LAKE MANAGEMENT STUDIES IN THE SANDHILLS WILDLIFE MANAGEMENT AREA

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ABSTRACT

The North Carolina Division of Game and Inland Fisheries is developing a wildlife management area, including several lakes, in the Sandhills country of the south-central part of the State. The lakes are being developed and managed for public fishing. Three lakes were opened for the first time in 1941, and in 1942 four lakes were opened to public fishing. All lakes were stocked with largemouth black bass, *Huro salmoides* (*Lacépède*), and mixed bluegills, *Lepomis macrochirus macrochirus* Rafinesque and *L. m. purpurescens* Cope. Special permits were sold, and all catches were weighed and measured. A season of 10 weeks was permitted in 1941, and one of 6 weeks in 1942. In 1941, 769 successful anglers caught 5,127 fish, weighing 2,611 pounds, from 121 acres of water. In 1942, 343 successful anglers caught 1,649 fish, weighing 853 pounds, from 142 acres of water. Two lakes opened in 1942 for the first time, following stocking with legal-length largemouth black bass and bluegills, showed returns of 38 per cent of the bass and 25 per cent of the bluegills in one lake, and returns of 10 per cent of the largemouth bass and 7 per cent of the bluegills in the other lake. This percentage of recapture throws some doubt on the advisability of stocking a new lake with legal-length fish in preparation for opening it to public fishing. There is evidence that the application of commercial fertilizer increased the yield of fish in one lake. Additional new lakes are under construction, and excellent opportunities will be presented for future studies in management and fish production.

INTRODUCTION

The North Carolina Division of Game and Inland Fisheries, with the aid of Federal funds obtained through the Pittman-Robertson program, is developing a wildlife-management area in the Sandhills of the south-central part of the State. Developments on this area include several small lakes which are intended primarily as waterfowl resting and feeding areas, but which also provide ideal environment for largemouth black bass and bluegill sunfish. The lakes offer excellent opportunity for carrying on a carefully managed fishery program. All lakes are amply supplied by small streams which are fed by permanent springs, and all are well protected against danger from floods by properly constructed dams.

DESCRIPTION OF THE LAKES

The lakes all have clear water which is stained a dark amber color by the organic material present. The hydrogen-ion concentration of the water has been found to vary between 5.2 and 7.0, depending upon the amount of dead and living vegetation in the lakes, the size of the tributary streams, and possibly other factors. The lakes are relatively

shallow; the depth does not exceed 20 feet, except in deep holes in the old creek channels. Shorelines slope gradually, and at least one-third of the total water area of each lake is less than 5 feet deep. The surface areas of the lakes range from 21 to 65 acres.

On the newer lakes, shorelines have only the original vegetation of the Sandhills uplands, which is predominantly longleaf pine, oaks, and wiregrass. On lower and moister lands and along streams vegetation is much denser and of more complex composition. In some localities the plant growth in the "bays" was left as shelter for fish and waterfowl.

McKinney Lake, which is part of the U. S. Fish and Wildlife Service fish hatchery located on the area, has a grove of small blackgum and cypress trees at its upper end. Broadacres Lake has several acres of alder, willow, and buttonbush shrub. Several species of aquatic uplants have become well established in the lakes. A variety of *Myriophyllum* soon becomes established, and frequently is a nuisance to fishermen. No satisfactory way of controlling this plant has been found, although intense fertilization seems to offer some relief. Bladderwort, *Utricularia* sp., is another pest plant which soon appears in the Sandhills Lakes. To date this plant threatens to become a nuisance only in Scotland Lake.

Record of Fish Stocked

Table 1 presents a record of fish stocked in the lakes which are described in this report. Most of the fish came from the Federal hatchery on the area; others were from rearing ponds operated by the State, also on the area, and from the State fish hatchery near Fayetteville. The data on fish released in McKinney Lake are probably incomplete; those for other lakes are essentially complete except as noted.

Most of the lakes were stocked with common bluegills, *Lepomis macrochirus macrochirus* Rafinesque, although a related subspecies, *L. m. purpurescens* Cope, occurs in the streams, and some of the fish released were of this variety. The two subspecies of bluegill appear to interbreed so that the characters of fish taken in the Sandhills Lakes are often intermediate, indicating hybridization of the two forms. The native fish reaches a larger size, and appears better adapted to available environments in this portion of the State.

Fishing Program

In 1941 a season of 10 weeks was set for public fishing in Broadacres, Kinney Cameron, and McKinney Lakes. The season began May 27 and ended August 2. Fishing from State-owned boats and from the dams was permitted between the hours of 7:00 a.m. and 7:00 p.m. This regulation prevented undue trampling of the shorelines, and provided an excellent opportunity to check on the catch of all fishermen. Creel checking stations were erected at each of the lakes with the help of C.C.C. labor. The State's creel limits were reduced one-half, so that

Table 1.—Record of fish stocked in the Sandhills lakes

Lake and date of impoundment	Area (acres)	Largemouth black bass			Bluegills		
		Number	Size	Date	Number	Size	Date
Broadacres[1] (Impounded Jan. 1936)	21	8,300	Fry	May, 1937	10,000	Fingerling	Dec. '36-May, '37
					34	Adult	Dec. '39
					119	Adult	May-Aug. '41
Kinney Cameron (Impounded Jan. 1936)	35	4,000	Fry	Apr.-May, '37	33,000	Fingerling	Dec. '36
		5,000	No. 1	June, '37			
		10,000	Fry	May, '38			
		6,000	No. 1	May, '40			
McKinney (Impounded Jan. 1936)	65	39,000	No. 2	Dec. '36	None reported, but some fish probably stocked.		
		13,000	Fry	Apr.-May, '37			
Scotland[2] (Impounded Dec. 1939)	21	11,000	No. 1	May, '40	5,200	Fingerling	March, '42
		154	Adult	Mar. '42	834	Adult	March, '42
Gum Swamp[3] (Impounded Feb. 1942)	65	653	Adult	Mar. '42	16,800	Fingerling	Feb.-Mar., '42
					792	Adult	March, '42

[1]In addition, the bass and bluegills contained in a 3-acre rearing pond were liberated in Broadacres Lake in the autumn of 1940. There is no record of the number of fish released at this time, but it was several thousands, and included both adults and small fingerlings.

[2]In addition, 30 adult warmouth bass, *Chaenobryttus coronarius* (Bartram), were released in the lake, March, 1942. In 1940 several adult bluegills were stocked by the County Game and Fish Protector.

[3]In addition, 70 yearling warmouth bass and 10 robin, *Lepomis auritus solis* (Cuvier and Valenciennes), were released February, 1942.

each angler could retain only 4 largemouth black bass and 10 bluegills, or not more than 20 of all species in any one day. All anglers purchased permits before beginning to fish. These permits were sold for 50 cents each, and were good for a day's fishing. Boats were rented at the rate of 50 cents per day. All catches were weighed, length of the bass measured, and all data recorded on a standard form. Creel-station attendants were hired to assist regular Division employees in manning the stations.

The same regulations were followed in 1942, except that the daily hours of fishing were changed to start at sunrise and end at sunset. A shorter season was employed, beginning May 30 and ending July 5. In 1942 four lakes were opened to fishing; two that were open in 1941, and two new lakes which had not been previously opened to fishing.

Creel Returns

From an examination of the data presented in Table 2, it is noted that the yield in pounds of fish per acre was considerably less from McKinney Lake in 1941 than from the other lakes that year. This low yield was a disappointment to many anglers who expected that since this lake was part of the Federal fish hatchery property it would be literally full of fish. The scarcity of small bluegills was particularly significant since it indicated an under-stocked condition in this lake. The small take can probably be explained by the fact that the lake had been drawn down the previous winter and some of the fish removed and distributed elsewhere. The lake will not be reopened until a satisfactory fish population has been reestablished.

The fishing returns for 1941 show that the average catch of each

Table 2.—Fishing returns, Sandhills Wildlife Management Area, during the 1941 season

Item	Lake			
	Broadacres	Kinney Cameron	McKinney	All lakes
Permits issued	657	725	775	2,157
Anglers' reports[1]	234	390	145	769
Number of days open to fishing	31	32	39	......
Hours of fishing	1,373	1,855	1,066	4,294
Number of all fish taken	1,667	3,064	396	5,127
Weight of all fish taken[2]	654	1,481	476	2,611
Acres of water	21	35	65	121
Yield (pounds per acre)	31.1	42.3	7.3	21.6
Average catch per hour (number)	1.2	1.6	0.3	1.2
Average creel (pounds)	2.8	3.8	3.3	3.4
Number of largemouth bass taken	103	244	214	561
Weight of largemouth bass taken	189	422	343	954
Average weight of largemouth bass	1.83	1.73	1.60	1.70
Undersized largemouth bass returned to water	167	383	7	557
Number of bluegills taken	1,378	2,717	133	4,228
Weight of bluegills taken	384	1,000	98	1,482
Average weight of bluegills	0.27	0.37	0.73	0.35
Undersized bluegills returned to water	442	218	49	709
Number of coarse fish taken	186	103	49	338
Weight of coarse fish	81	59	35	175

[1]Anglers that did not catch any fish were not required to complete the creel-census form.
[2]All weights are in pounds or fractions thereof.

successful angler was 3.4 pounds of fish, or 6.6 fish. Largemouth black bass made up slightly more than 10 per cent of the total number of fish taken, and bluegills 82 per cent of the total catch. Largemouth black bass made up 36 per cent of the total catch by weight, and bluegills 56 per cent. The remainder consisted of coarse fish, including the chain pickerel, ***Esox niger*** Le Sueur (known locally as jack), bullheads, ***Ameiurus*** sp., eels, ***Anguilla bostoniensis*** (Le Sueur), and large golden shiners, ***Notemigonus crysoleucas boscii*** (Valenciennes). The yield of 42 pounds per acre from Kinney Cameron Lake was considered good. Anglers were well pleased with the facilities available for their recreation, and many parties returned to the lakes several times. It must be recognized that the anglers fishing in Broadacres and Kinney Cameron Lakes in 1941 reaped the harvest of five growing seasons. However, it is quite likely that these lakes had already passed the peak of their natural productivity by 1941.

The creel returns for the 1942 season are summarized in Table 3. The number of anglers purchasing permits decreased by 68 per cent, while the percentage of anglers catching fish rose from 35 in 1941 to 50 in 1942. The average catch per hour of fishing in all lakes dropped from 1.2 fish in 1941 to 0.8 fish in 1942. The average catch of the successful anglers in 1942 was 2.5 pounds of fish, or 4.8 fish each. Largemouth black bass made up 14 per cent of the total number of fish taken, and bluegills 76 per cent of the total catch. By weight, largemouth bass made up 35 per cent of the total, and bluegills 53 per cent. The

Table 3.—Fishing returns, Sandhills Wildlife Management Area, during the 1942 season

Item	Lake				
	Broadacres	Gum Swamp	Kinney Cameron	Scotland	All lakes
Permits issued	238	119	204	122	683
Anglers' reports[1]	158	35	89	61	343
Number of days open to fishing	11	11	11	11	......
Hours of fishing	818	168	540	371	1,897
Number of all fish taken	889	132	351	277	1,649
Weight of all fish taken[2]	375	111	198	169	853
Acres of water	21	65	35	21	142
Yield (pounds per acre)					
Average catch per hour (num-	17.9	1.7	5.7	8.0	6.0
ber)	1.0	0.8	0.6	0.7	0.8
Average creel (pounds)					
Number of largemouth bass taken	2.4	3.2	2.2	2.8	2.5
Weight of largemouth bass taken	57	68	54	55	234
Average weight of largemouth bass	74	81	60	84	299
Undersized bass returned to	1.3	1.2	1.1	1.5	1.3
water	83	19	578	170	850
Number of bluegills taken	728	58	265	208	1,259
Weight of bluegills taken	237	27	114	79	457
Average weight of bluegills					
Undersized bluegills returned	0.33	0.47	0.43	0.38	0.36
to water	139	6	38	133	316
Number of coarse fish taken	104	6	32	14	156
Weight of coarse fish	64	3	24	6	97

[1]Anglers that did not catch any fish were not required to complete the creel-census form.
[2]All weights are in pounds or fractions thereof.

largest fish caught during both seasons was a largemouth black bass, weighing 10 pounds, 2 ounces, taken in Broadacres Lake, May 31, 1942.

A more accurate comparison between 1941 and 1942 can be made for Broadacres and Kinney Cameron Lakes, which were fished both years. The average catch per hour both in fish and in pounds of fish in 1942 dropped very little in Broadacres Lake below the 1941 returns, but the total yield dropped from 31.1 pounds per acre to 17.9 pounds per acre. Broadacres Lake returned the best yield of all the lakes in 1942. This relatively greater productivity may be attributed to a program of fertilization. The stream supplying the lake is impounded to form a rearing pond of 3 acres just above Broadacres Lake. This pond was treated with 2,800 pounds of 6-9-3 fertilizer and 500 pounds of nitrate of soda between April 11 and July 1. Much of this fertilizer found its way into Broadacres Lake. In addition, 7,200 pounds of 6-9-3 fertilizer were applied to the shallow coves of Broadacres Lake between April 11 and June 11. It was planned that the fertilization program should be carried through the season, but a shortage in available funds necessitated the abandonment of this plan. Enough fertilizer was applied that a bloom was in evidence at least half of the time, and the transparency of the water was decreased appreciably.

The returns from Kinney Cameron Lake in 1942 were not expected in view of the relatively good yield in 1941. The number of anglers using the lake in 1942 was only 23 per cent of the number in 1941, while the yield in pounds dropped to 13 per cent of that of the preceding year. Even more marked was the change in the number and size of the largemouth black bass. The size distribution of 244 legal-length bass taken in 1941 indicated a satisfactory balance between large and small fish of this species (Table 4.). Although the number of undersized fish reported in 1941 was greater than in the other lakes, no abnormal condition was thought to exist. In 1942, however, 10 undersized bass were reported for every one that was 12 inches or more in total length. In fact, the number of small bass taken, most of which were between 10 and 11.5 inches long, was probably considerably greater than the number actually reported. It appears that a serious unbalance existed in the fish population of Kinney Cameron Lake during the 1942 season. There are several possible explanations for the change since 1941. The abundant small bass represent a single year class which appears to have been spawned in 1940. An examination of the scales of several of these fish indicated that growth had been very poor in 1942. The small number of undersized bluegills (less than 6 inches, total length) reported in 1942 indicates a possible shortage of forage for the young bass. The lake contains relatively few forage fishes. In 1941 bluegill beds were well distributed over the lake, while in 1942 only one bed (a group of several nests) was located. It is possible that the bluegills which were stocked as fingerlings were mostly caught in 1941. These fish, for some unknown reason, may have failed to reproduce. The disappearance of the large bass from the

Table 4.—Length distribution of largemouth black bass

Lake	12 to 13.9 inches	14 to 15.9 inches	16 to 17.9 inches	18 to 19.9 inches	20 to 21.9 inches	22 inches and over	Total
	Size classes (total lengths)						
	1941 season						
Broadacres	47	13	32	13	1	7	103
Kinney Cameron	82	80	39	23	20	....	244
M Kinney	82	80	24	16	6	6	214
Totals	211	173	85	52	27	13	561
	1942 season						
Broadacres	45	6	3	2	....	1	57
Kinney Cameron	47	1	....	3	3	....	54
Gum Swamp	56	10	2	....	....	....	68
Scotland	31	12	9	3	....	....	55
Totals	179	29	14	8	3	1	234

lake is so far unexplained. It is interesting to note that Kinney Cameron Lake has the cleanest basin and shoreline, and the clearest water of any of the lakes on the Area. The upper arms of the lake, however, have good escape cover for small fish in the form of aquatic vegetation, brush, and logs.

The creel returns from Scotland Lake are especially interesting in that the lake was stocked with adult fish in the spring of 1942 (Table 1). These fish were obtained from rearing ponds on the Area and from the State hatchery at Fayetteville. Thirty-eight of the 154 largemouth black bass stocked in March 1942 were jaw-tagged (National Band and Tag Company, monel-metal tags, No. 1242M). Fourteen, or 37 per cent of these tagged fish were retaken by anglers. Twelve of the 154 adult bass listed in Table 1 probably did not reach legal size during the open season, so can be excluded from the returns. Consequently, there were 104 untagged bass of legal length that were available to the anglers. Forty-one, or almost 40 per cent of these fish were taken. It was observed that every tagged fish recovered showed some irritation about the tag, which was placed on the premaxilla. Some largemouth bass showed extensive swelling and infection. All tagged fish were weighed and measured at the time of release and again when recovered. The total length of these bass varied from 13 to 17 inches, and the weight from 1 to 2 pounds at the time of release. The length of two bass increased 1 and 2 inches, respectively, and the weight of one increased 0.3 pound. All other measurements were essentially the same as when the fish were released. The undersized bass reported (170) are thought to represent the original stocking of 11,000 No. 1 fingerlings released in May, 1940. The bluegills taken represented only one-fourth of the number released as legal-length fish the previous March.

Gum Swamp Lake, impounded in February, 1942, and stocked with legal-sized largemouth black bass and bluegills, gave opportunity to determine the ability of anglers to take fish from a new lake under rather difficult conditions. This lake basin contains many logs, stumps, and much bushy growth. The records show that angling success was

poor. Only 68 largemouth black bass (10.4 per cent) were recovered from a total of 653 that were stocked only a few weeks prior to the opening of the season. The under-sized bass reported from this lake are thought to have been resident in the stream before the lake was impounded. The adult fish released in this lake were taken in Currituck Sound by seining, and were transported by truck to Gum Swamp Lake. The cost of obtaining these bass, including wages, transportation, and travel, amounted to $0.305 for each fish. This cost is considerably less than that of preducing fish of the same size in an ordinary hatchery. Only 58 legal-length bluegills (7.3 per cent) were taken in Gum Swamp Lake from an available stocking of 792. The results obtained by opening this lake to fishing were not satisfactory. However, if a greater number of anglers had used the lake, or if the opening of the season had been postponed a few weeks, the take might have been much greater.

General Comments

Fishing throughout the Sandhills of North Carolina was unusually poor in 1942. No reason for this low productivity has been found, yet the statement has been heard many times from reliable anglers and is supported by creel-census data. It is possible that adult largemouth black bass were decimated by disease, but no evidence has been found to substantiate this theory. Young bass less than 12 inches long were present in abundance.

The possibility is suggested that the fingerling bluegills released in some of the lakes represented hybrid stocks, and as such failed to reproduce. The bluegills taken in Kinney Cameron Lake in 1942 were dominantly the native variety, *L. m. purpurescens* Cope.

A program of fertilization is contemplated for some of the lakes on the management area, particularly Kinney Cameron. It is believed that natural reproduction should maintain adequate numbers of game fishes on these lakes so that with a carefully planned open season, no restocking should be necessary. Although the percentage of legal-length fish that were retaken by anglers was below the figure anticipated, those fish which remain are available as breeders and should contribute to fishing in future seasons.

A wider use of jaw tags as a means of gaining information on the fish population is recommended. Care must be exercised, however, to prevent serious injury to the fish through infection caused by the tag.

The Management Area, including the lakes, has been taken over by the Army, and a public fishing program cannot be resumed until after the war. Four additional lakes were impounded during 1942. When the war ends, the lakes on this area will again offer exceptional opportunity for research on fish populations and the management of small lakes for public fishing. The management of these lakes has proved to be one of the most interesting phases of the State's inland-fishery program.

A COMPARISON OF THE HOOP-NET CATCH ON SEVERAL WATERS IN THE TENNESSEE VALLEY BEFORE AND AFTER IMPOUNDMENT[1]

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ABSTRACT

Identical hoop nets were set in two pre-impoundment areas and in one reservoir in the Tennessee Valley to note differences in the relative abundance of fish before and after impoundment. In one pre-impoundment area (Holston River) 107 net lifts yielded 321 fish (300 fish per 100 lifts); in the other pre-impoundment area (Tennessee River) 583 fish were taken in 148 net lifts (394 fish per 100 lifts). The four major habitats in Wheeler Reservoir yielded 17,087, 877, 1,590, and 947 fish, respectively, per 100 lifts. It seems that fish are much more abundant in the reservoir than in the several pre-impoundment areas.

INTRODUCTION

When the dams now under construction have been completed, the entire length of the Tennessee River, except for a few miles near its mouth, will have been converted into a series of reservoirs. Many tributary waters, too, have been impounded. This decided change in habitat greatly influenced the fish population and the fishing in the Tennessee River system. That fishing intensity has increased after impoundment is shown by Eschmeyer.[3] It is true also that the total water area is increased several fold as the result of impoundment. Has there been an increase also in the number of fish per acre? The present study is an attempt to answer that question partly.

During 1941 hoop nets[4] were set in that part of the Tennessee River which was to become Watts Bar Reservoir and in that part of the Holston River which was to become Cherokee Reservoir. During the same period identical hoop nets were set in Wheeler Reservoir which had been completed in 1936.

Nets were generally fished in one location for several days, though they were always lifted daily. Some were examined as often as four times during a 24-hour period to note differences in the catch at different periods of the day, but in these instances data were combined for

[1]Published by permission of the Tennessee Valley Authority.
[2]Both authors left for the armed services before this paper could be completed. It was finished by R. W. Eschmeyer, who also supervised the work.
[3]Eschmeyer, R. W. The effect of impoundment on fishing intensity in several TVA waters. (To appear in the same volume with the present paper.)
[4]Description of hoop nets: Equipped with 6 circular hoops having the following diameters in feet from front to back—4½, 4¼, 4, 3¾, 3½, and 3¼. First throat 16 meshes long, finished with 4 strings, and second throat 21 meshes long. Front 32 meshes of net, 1½-inch bar measure; remaining 84 meshes, 1-inch bar measure. Each net equipped with wings of 1½-inch bar measure, 80 meshes long, No. 15 thread, and lead 40 feet long, 1½-inch bar measure, No. 12 thread.

the several lifts to determine the total daily catch. The lifts, as used in the comparisons below, therefore, followed sets covering a period of 20 to 24 hours, and invariably included the periods during which most fish were ordinarily caught. It was found that very few fish entered the nets between late morning and late afternoon, the time when changes were made in netting locations. Differences of a few hours in the length of the sets were therefore ignored. The netting period extended, intermittently, from early April to late September.

In the rivers the nets were necessarily set in relatively shallow running water; in the reservoir some nets were fished much deeper and many sets were made in water having imperceptible movement. Wings were used on the nets where conditions permitted, but in very fast water the nets were fished without wings.

Netting on the pre-impoundment areas was carried out by the first author and that on Wheeler Reservoir was conducted by the second author. Thanks are due to Dr. A. H. Wiebe, Chief of the Biological Readjustment Division, and Dr. C. M. Tarzwell for helpful suggestions, and to various members of the Biological Readjustment Division for assistance in the field.

The netting data are considered separately for the two pre-impoundment areas. A comparison then will be made of the take in one of these areas and that in Wheeler Reservoir.

Catch in the Cherokee Reservoir Area

The Cherokee Reservoir area is on the Holston River in eastern Tennessee. The Holston is one of the main tributaries of the Tennssee. In fact, it unites with the French Broad above Knoxville to form the Tennesse River. It is a shallow, moderately fast-flowing river consisting of alternating pools and riffles throughout its entire length. The water over the riffle is shallow (one-half foot to 5 feet), but it may become 20 feet or deeper in the pools below the riffles. Most of the tributary streams are small, originating in cool, clear springs. The water in the Holston River is always very clear during periods of normal flow and becomes muddy only during periods of heavy rainfall. The bottom is composed of rock or gravel in the riffles and sand and gravel, with a small amount of mud, in the pools. The river receives both industrial wastes and domestic sewage from several communities above the reservoir area. At times the pollution has caused extensive fish mortality, and it may have been sufficiently severe to affect the fish population at all times.

Hoop netting on the Holston was confined to two general areas, one near the dam site and the other about half way between the dam and the upper end of the future reservoir. Here, as in Watts Bar area, construction was already in progress on the dam; therefore, the original stream conditions had been altered in the lower area to the extent that the water was a few feet deeper and the current weaker due to the cofferdams and the partial closure of the dam itself. This section

seemed typical of the pool areas of the Holston River. Here the nets were set in water from 5 to 15 feet deep.

The upper area was located about a mile below Morristown, Tennessee, about 23 miles upstream from the dam. Typical river conditions prevailed in this area. The water was shallow, ranging from 2 to 5 feet deep, and the current was strong at all times. About the only unusual condition in this area was the discharge of the Morristown sewage about a mile above the netting area. This sewage may have affected the distribution of some species to some extent.

A total of 107 hoop-net lifts were made in the Cherokee Reservoir area, 50 in the lower section and 57 is the upper section. The entire take consisted of 321 fish weighing 192 pounds. The catch is indicated by species in Tables 1 and 2. The catch differed considerably between the two areas. Only mud catfish and rock bass were more commonly taken in the lower portion of the area.

Though a considerable number of species were represented in the catch, the total take was small, especially in the lower area. It was noted that more fish were taken when the water was muddy (and above normal level). In the lower area, for example, the catch was only 0.9 fish per net when the water was clear. It rose to 2.1 fish per net when the water was slightly turbid.

Catch in the Watts Bar Reservoir Area

Watts Bar is the second of nine reservoirs (several of which are under construction) on the Tennessee River. Nets set in the Tennessee in the Watts Bar Reservoir area were placed in three general localities. In the lower of these sections backwater conditions existed to some extent at the time of netting, and river conditions were not as typical as in the other two sections, because the dam had been partially completed and cofferdams were across the other portion of the river, impounding some water. However, since the total flow of the river

Table 1.—Hoop-net catch data, by areas, in the Cherokee Reservoir area (Holston River), 1941

Species	Number captured in	
	Upper area	Lower area
Long-nosed gar	3	1
Mooneye	1	....
Buffalo	1	....
Carpsucker	1	....
Carp	37	15
Redhorse	44	7
Hog sucker	....	1
Channel catfish	23	3
Mud catfish	35	23
Bullhead	2	....
Sauger	24	2
Smallmouth black bass	1	....
Kentucky bass	15	5
Largemouth black bass	2	....
Rock bass	15	19
Long-eared sunfish	18	6
Bluegill	14	3
Total	236	85

Table 2.—Species, number, weight, and average length of fish taken in 107 hoop-net lifts in the Cherokee Reservoir area (Holston River), 1941

Species	Number	Average weight (pounds)	Average length (inches)
Long-nosed gar	4	1.2	25.6
Mooneye	1	0.3	9.7
Buffalo	1	2.4	16.6
Carpsucker	1	1.2	13.3
Carp	52	0.4	9.0
Redhorse	51	0.5	10.0
Hog sucker	1	0.8	12.2
Channel catfish	26	0.7	12.9
Mud catfish	58	1.3	14.0
Bullhead	2	0.7	11.4
Sauger	26	0.5	12.0
Smallmouth black bass	1	0.4	10.1
Kentucky bass	20	0.3	8.9
Largemouth black bass	2	0.6	10.3
Rock bass	34	0.2	6.8
Long-eared sunfish	24	0.1	4.8
Bluegill	17	0.2	6.2
Total	321	0.6	10.4

was allowed to go through the lock section or over the spillway section of the dam, almost the only change from original river conditions lay in an increase in depth of several feet together with a reduction in the rate of flow. The river was still confined to its original channel and there was always a perceptible current. The water was never clear, and at times was very muddy. The depth of the water in this section varied from 2 to 20 feet, and the bottom was covered with mud. Here the netting was in an area from 1 mile to within 200 feet of the dam site.

The netting in the middle section was around the lower end and on both sides of Half Moon Island which is located about 20 miles upstream from the dam site. Typical river conditions prevail in this section. A portion of the water is diverted into a narrow channel around the island by low navigation dams at the upper end, but these dams have become ineffective through lack of repair, and a large volume of water flows over them and forms a wide, shallow channel on the north side of the island. Here the water is from 1 to 5 feet deep. The water in the narrow channel on the south side of the island is from 4 to 6 feet deep and the current is very strong. There are deeper pools below this island. The water in this section is clearer than in the lower area, and the river bottom is composed of a combination of rock, gravel, and sand.

The netting in the upper section was conducted around the lower end of Long Island and in the channels on each side of the island. This island is located about 2 miles above Kingston, Tennessee, where the Clinch River empties into the Tennessee, and about 40 miles upstream from the dam site. This area is very similar to the middle section as to depth, intensity of the current, and the nature of the river bottom. The water was clearer here than in the middle and lower sections but, as in the other areas, its turbidity varied with the rainfall in the drainage basin.

During the months of May, June, and July 1941, a total of 148 overnight net lifts were made in the Watts Bar Area in the three locations described above. The numbers in the individual sections were: 71 in the lower; 36 in the middle; and 41 in the upper. These lifts yielded a total of 583 fish weighing 401 pounds. The catch is tabulated according to number and average size in Table 3.

A comparison of the fish catch from different portions of the reservoir area (Table 4) provides some interesting information regarding the local differences in the abundance of the various species. The carp, mud catfish, bluegill, black crappie, and drum (sheepshead) were more abundant in the lower area where, as stated before, the water was more turbid and deep, the current weaker, and the river bottom covered with mud. These species generally decreased in the catch from the lower to the upper area. Such fish as the redhorse, channel catfish, sauger, Kentucky bass, and white crappie were more abundant in the catch in the middle and upper areas, which are characterized by gravel and rocky bottom, and clearer, shallower water with a stronger current. It is also interesting to note that the total number and pounds of fish taken per 100 net lifts shows a definite increase downstream. The catch per 100 lifts and the average weights of the fish taken are indicated in Table 4.

Table 3.—Species, number, weight, and average length of fish taken in 148 hoop-net lifts in the Watts Bar Reservoir area (Tennessee River), 1941

Species	Number	Average weight (pounds)	Average length (inches)
Short-nosed gar	1	0.6	9.6
Long-nosed gar	11	1.1	22.6
Mooneye	2	0.2	7.2
Buffalo	2	1.2	11.3
Carpsucker	1	0.2	7.0
Carp	49	2.0	14.2
Common sucker	5	0.7	12.2
Redhorse	40	0.5	9.8
Channel catfish	22	0.3	9.8
Blue catfish	12	0.4	9.2
Mud catfish	127	1.3	14.3
Bullhead	2	0 4	13.2
White bass	3	0.7	10.8
Sauger	13	0.6	12.4
Smallmouth black bass	2	0.6	9.6
Kentucky bass	54	0.7	10.4
Largemouth black bass	4	0.6	10.6
Warmouth bass	5	0.3	6.9
Long-eared sunfish	4	0.1	4.9
Bluegill	115	0.2	5.7
Black crappie	56	0.1	5.1
White crappie	28	0.3	8.5
Drum	25	0.2	7.8
Total	583	0 7	10.0

Comparison with Catch in Wheeler Reservoir

In the Wheeler Reservoir hoop netting (Miller[5]), all four major divisions of the reservoir were netted. The sets included 40 in the tail

[5]Miller, Lawrence F. A comparison of the hoop net catches in several fish habitats of Wheeler Reservoir (MS.).

water at the head of the reservoir, 24 in the upper section, 145 in the middle area, and 71 in the lower region. As noted by comparing Tables 1, 4, and 5 the catch in each major area was much higher than in the river before impoundment.

Wheeler and Watts Bar Reservoirs will be similar in most respects. Both are main-stream reservoirs on the Tennessee. It may be expected that the fish population in Watts Bar Reservoir 5 years from now will not differ greatly from the population in Wheeler Reservoir at the time of netting. Cherokee Reservoir will be of the storage type, similar to Norris Reservoir, and its fish population will differ rather decidedly from that found in the main-stream reservoirs. A comparison of the catch in the Holston and in Wheeler is, therefore, of little value, but it may be expected that the difference between the take in the Watts Bar

Table 4.—Hoop-net catch data, by areas in the Watts Bar Reservoir area (Tennessee River), 1941

Species	Catch per 100 net lifts			Average weight (pounds)		
	Upper area	Middle area	Lower area	Upper area	Middle area	Lower area
Short-nosed gar	....	....	1	....	....	0.6
Long-nosed gar	5	3	11	0.6	2.0	1.1
Mooneye	....	6	....	....	0.2	....
Buffalo	....	....	3	....	....	1.2
Carpsucker	2	....	....	0.2	....	....
Carp	5	....	65	0.7	....	2.0
Common sucker	....	....	7	....	....	0.7
Redhorse	24	58	13	0.4	0.6	0.4
Channel catfish	32	6	10	0.3	0.2	0.3
Blue catfish	10	....	11	0.7	....	0.2
Mud catfish	32	58	129	1.1	1.7	1.2
Bullhead	....	....	3	....	....	0.4
White bass	2	6	....	0.5	....	....
Sauger	5	17	7	0.3	0.5	0.8
Smallmouth black bass	....	3	1	....	0.7	0.4
Kentucky bass	32	75	19	0.4	0.7	0.8
Largemouth black bass	....	8	1	....	0.6	0.6
Warmouth bass	2	11	....	0.2	0.3	....
Long-eared sunfish	5	....	3	0.1	....	0.1
Bluegill	41	47	113	0.2	0.2	0.2
Black crappie	2	39	57	0.3	0.1	0.1
White crappie	29	22	11	0.3	0.3	0.4
Drum	2	....	33	0.4	....	0.2
Total	230	359	498	0.4	0.7	0.8

area and Wheeler Reservoir may be attributed largely to impoundment of the Tennessee River in the Wheeler area.

The best average catch in Watts Bar region was about 5 fish per net (lower area). The poorest average catch on Wheeler Reservoir was almost 9 fish per net lift (upper area); the best was 170 fish per lift (tail water). It seems, therefore, that fish are much more abundant in the reservoir than in the river before impoundment. An examination of the catch records suggests, too, that game and pan fish are relatively much more abundant in Wheeler Reservoir (where they comprised 98.7, 84.4, 84.7, and 91.0 per cent, respectively, of the catch in the four areas) than in the Tennessee River in the Watts Bar Reser-

Table 5.—Catch per 100 hoop-net lifts in the four major habitats of Wheeler Reservoir, 1941

Classification and species	Tail water	Upper reservoir	Middle reservoir	Lower reservoir
Coarse fish:				
Short-nosed gar	11	13	24	2
Long-nosed gar	22	4	4	1
Dogfish	....	....	1	....
Mooneye	12	....	1	....
Skipjack	9	....	1	2
Gizzard shad	32	16	66	38
Bigmouth buffalo	....	....	2	....
Black buffalo	....	....	6	....
Smallmouth buffalo	....	....	43	9
Quillback carpsucker	....	4	3	....
Common sucker	....	....	....	....
Hog sucker	....	....	....	....
Spotted sucker	....	....	10	....
Silver mullet	....	....	1	1
Ohio redhorse	....	4	2	2
Carp	15	4	20	13
Food fish:				
Channel catfish	....	....	6	....
Blue catfish	....	....	2	1
Mud catfish	44	13	11	11
Black bullhead	76	....	....	1
Brown bullhead	....	4	27	....
Yellow bullhead	....	....	5	....
Drum	8	75	8	4
Game fish:				
Chain pickerel	....	....	3	....
White bass	139	....	38	1
Yellow bass	....	....	3	....
Sauger	12	....	1	....
Kentucky bass	21	4	1	31
Largemouth black bass	....	....	4	....
Warmouth bass	3	4	2	4
Panfish:				
Green sunfish	....	....	1	4
Long-eared sunfish	....	....	1	1
Sunfish (Sp.)	....	....	3	25
Bluegill	212	137	206	195
Long-eared sunfish	2	....	5	14
Rock bass	....	....	1	....
Black crappie	14,578	354	385	165
White crappie	1,891	241	693	422
Total	17,087	877	1,590	947

voir area (where they comprised 49.3, 63.7, and 51.7 per cent of the catch in the three general localities).

A close comparison cannot be made of the fish populations in the pre-impoundment areas and in the reservoir, for several reasons:

1. Though each major habitat was fished, both in the rivers and in the reservoir, local environmental differences undoubtedly influenced the catch. Comparable sets could not be made, for example, in the lower portions of the rivers and in the lower third of Wheeler Reservoir, because of differences in depth, flow, turbidity, and other factors.
2. In most areas the nets were fished with wings, but in some localities wings could not be used.
3. In fast water the nets invariably faced downstream; elsewhere the nets were set at various angles with reference to the current.
4. Because of net selectivity, the relative abundance of various species in the populations undoubtedly differed from the relative abundance of these species in the catch.

It seems, nevertheless, that the decided differences in the catch of certain species in the rivers and in the reservoir very probably reflect actual differences in abundance of these fish. The large differences in the catch of both species of crappie, for example, can hardly be attributed to errors of sampling. Though exact comparisons cannot be made, it appears that an increase in the density of the fish population may be expected after impoundment, and that this increase applies to game fish and panfish as well as to other groups.

GAIN IN WEIGHT PER DAY AS A MEASURE OF PRODUCTION IN FISH REARING PONDS

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ABSTRACT

The variation in production due to ecological factors, some of which are beyond the control of the operator, is demonstrated for largemouth black bass ponds. A comparison of effectiveness is made between inorganic and organic fertilizers on the basis of survival and weight of fish per acre, which are ordinarily used as a measure of productivity.

Data are presented to show how survival and yield per unit area may be affected by manipulation and intentional interference by the operator. The gain in weight per acre per day is calculated to show that number or weight of fish per acre is not a reliable measure of the effectiveness of fertilizers.

Information on gain in weight per acre per day is presented on other waters in two series of experiments to demonstrate the applicability of this measure in comparing the productivity of different waters or various combinations of fertilizers.

INTRODUCTION

In the evaluation of the effect of fertilizers upon production, comparisons of the data from various sections of the country and even from pond to pond at the same hatchery are rendered difficult by a number of factors. Some of these factors are related to biological conditions and others are purely physical. The most apparent ones may be enumerated.

Inasmuch as the largemouth black bass completes the spawning activity within a very short period of time in any one area, the ponds at a hatchery are stocked within a few days of each other. At the end of the season it is physically impossible to schedule draining so that the total number of days of growth is the same in each pond, especially if research is being conducted in regulation-sized hatchery ponds. As a result, the growth period from pond to pond may vary by as much as a month or more, resulting in tremendous differences in weight and some differences in the length of the fingerlings. In some instances the differences in the growth period have been much greater than a month due to the delay in draining of ponds made necessary by the research program.

Many ecological factors affect weight, size, and numbers in ponds producing largemouth black bass. Cannibalism is the most important of these factors in that it may result in considerable variation in number per acre, or in the individual size of the fingerlings. In two adjacent ponds with apparently identical ecological conditions, cannibalism may reduce the population greatly in one while in the other there may be no cannibals. Consequently one pond will contain a

small number of fingerlings that vary considerably in size, and the other a large number of uniform-sized fingerlings.

In experimental work conducted at the hatchery of the Fish and Wildlife Service at Welaka, Florida, cannibals have been largely eliminated, but there is still considerable variation in the number and weight of the fingerlings produced per acre. This variation may result from any one of a number of factors. Some losses may be due to handling when the fry are being counted into the pond; other losses are probably due to habitat conditions, such as a water bloom, which prevents proper feeding; the cause of still further losses has not been explained.

A final, and important factor, is related to the method of pond con-

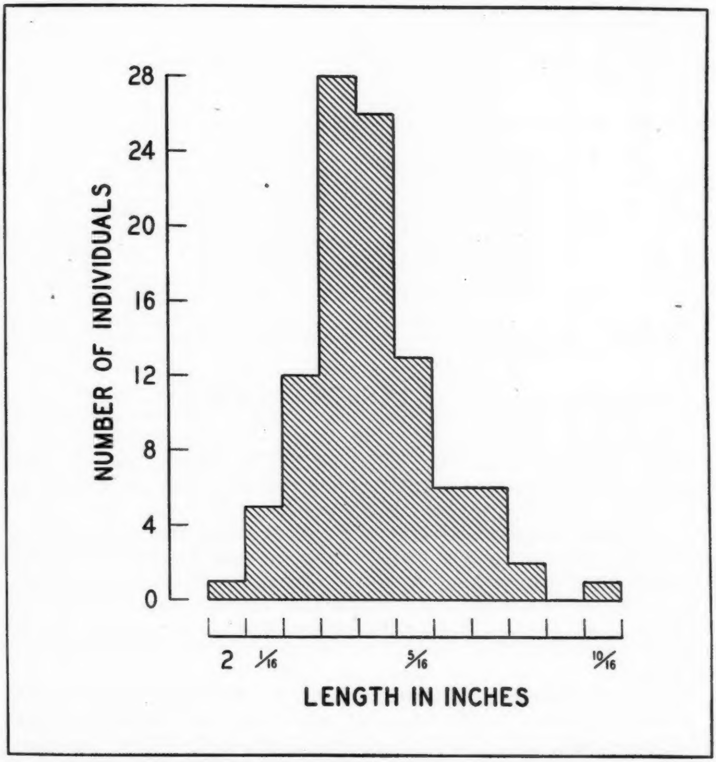

Figure 1.—Length frequency distribution in a pond having 100 per cent survival.

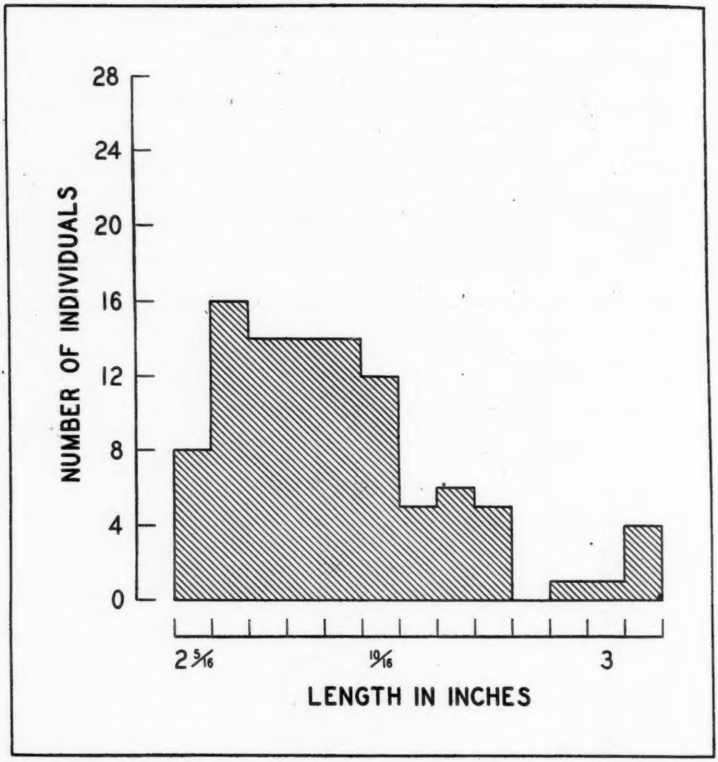

Figure 2.—Length frequency distribution in a pond having 54 per cent survival.

trol practiced in this particular series of experiments. Measurement of a representative number of fingerlings in each pond at regular intervals has been a routine procedure. From these measurements size-frequency curves are plotted. Ponds that contain fingerlings with a wide range of size distribution are drained first since cannibals are becoming numerous; those with little variation in size distribution are drained last.

This use of frequency distribution can be illustrated from Figures 1 and 2 which are length-frequency histograms of fingerlings taken from two ponds. Pond 10 had a survival of nearly 100 per cent and the size distribution is closely grouped about a fairly well defined mode (small standard deviation). The fingerlings taken from Pond 11 were

not distributed over a wider range of sizes, but the curve is flatter and the lengths more equally distributed (standard deviation greater). This pond had a survival of 54.4 per cent. When differences such as these begin to show up in the regular periodic measurements, a pond like No. 11 is drained early, and one like Pond 10 is placed among those to be drained last.

This procedure for determining the sequence in which various ponds will be drained has resulted in the acquisition of some unusual data. Under normal circumstances, with unselected ponds, there would be fewer and larger fish as the season progressed so that the ponds drained last would produce the smallest number of individuals. By the method of selection used here, the environmental resistance which results in a reduction in population is greatest in the ponds drained first and least in the ponds drained last so that, contrary to the normal expectations described above, the percentage of survival is highest in the ponds drained last. Table 1, Column 3, illustrates the typical relationship. This situation is due to the deliberate selection for later draining of ponds containing fish whose lengths are grouped most closely about the mean, for it is in these ponds that the environmental resistance reducing populations has been minimized.

Table 1.—Length of largemouth black bass fingerlings, survival, and weight per acre as related to days of growth

[Based on a combination of data for several ponds treated with a variety of fertilizers.]

Days of growth	Pounds per acre	Percentage of survival	Length (inches)
55	38.9	39	2.42
61	54.3	65	2.45
63	70.5	73	2.60
65	79.8	76	2.45
94	132.4	86	3.06

In most ponds length increases with time due to the reduction in populations by cannibalism or other factors that are absent in ponds drained according to the plan outlined. Contrary to the ordinary situation, the average length of the fingerlings from these ponds in which one survival rate approached 100 per cent, was about the same at draining regardless of time. It has already been demonstrated[1] that if the ponds are stocked with an adequate population, growth will stop at about the size shown in Table 1. The rate of stocking employed uniformly through this series of experiments was 15,000 fry per acre.

Experimental Results From Different Types of Fertilizer

It is readily apparent that the procedure of selecting ponds for draining according to the standards mentioned is advantageous to

[1]Meehean, O. Lloyd,
1940(a). Progress of biological inquiries, Welaka, Florida, 1939, 44 pp. (Unpublished).
1940(b). The development of a method of the culture of largemouth bass in fertilized ponds on natural food. Ph.D. dissertation, Ohio State University, 104 pp. (Unpublished).

Table 2.—Bass production in ponds treated with inorganic fertilizers

Days of growth	Pounds per acre	Gain in weight per acre per day	Percentage of survival
44	39.2	0.89	31
47	70.6	1.50	62
47	47.3	1.01	40
66	86.3	1.31	87
70	46.1	0.66	42

hatchery practice since it results in large populations. However, it has affected statistics on both the percentage of survival and weight per acre in such a way as to make the comparisons of various ponds fertilized with different fertilizers or by different methods very difficult.

For example, during the past 3 years inorganic fertilizer has been used in some ponds in order to obtain a comparison with results from the organic fertilizers ordinarily used in pond research. In every pond where inorganic fertilizer was used, the survival was much lower than in ponds fertilized with cottonseed meal, (Tables 2 and 3) and the ponds had to be drained early. It is believed, however, that this result is due to ecological factors, such as heavy water bloom, rather than to the type of fertilizer. (See Table 5).

As a result of experimental work over a period of years, the conclusion has been reached that, in the same waters, if an equivalent amount of nitrogen is used and other elements are supplied in the amounts needed, the production of fingerlings should be the same with all fertilizers. That is, lower survival and fewer pounds of fish per acre are not necessarily results of the fertilizers used, but probably are dependent upon ecological conditions which can be controlled with experience in the judicious use of different kinds of fertilizers.

Tables 2, 3, and 4 show the data collected on inorganic fertilizer, cottonseed meal, and other organic fertilizers, arranged according to the number of days of growth. In these tables the variation from pond to pond in the weight of fish produced per acre and in the survival should be noted. These data appear to be a mass of information with so much variation that valid comparisons are precluded. However, it would seem that production in some way should be related to the length of the growing period. From the standpoint of hatchery production those ponds with the largest survival and biggest fish may be

Table 3.—Bass production in ponds treated with cottonseed meal

Days of growth	Pounds per acre	Gain in weight per acre per day	Percentage of survival
36	84.3	2.34	85
47	74.1	1.58	68
48	33.3	0.69	47
50	72.5	1.45	86
59	37.2	0.63	37
67	49.9	0.74	50
71	129.0	1.82	84
71	73.1	1.03	73
82	65.6	0.80	72
113	84.5	0.75	63
138	176.3	1.27	83

Table 4.—Bass production in ponds treated with organic fertilizers other than cottonseed meal

Days of growth	Pounds per acre	Gain in weight per acre per day	Percentage of survival
61..............	58.3	0.96	100
68..............	61.6	0.91	68
72..............	91.8	1.27	92

considered as the most successful. From a biological standpoint ponds yielding the greatest weight per acre are the most successful.

To determine the value of comparisons according to weight produced per acre for varying periods of growth the coefficient of correlation between the number of days of growth and the total weight of fish produced per acre was calculated using information gathered from all ponds regardless of the type of fertilizer used.

For purposes of this study the standard modification for calculating the coefficient of small samples was used. The coefficient of correlation between the number of days of growth and the weight of fish produced was $r = 0.63$. According to the table "Values of the correlation coefficient for different levels of significance," (Fisher, 1940; p. 214), r for 17 degrees of freedom falls between $p = .01$ and $.001$. This correlation is highly significant and indicates the close relationship between the weight of fish produced and length of the growing period. It seems necessary therefore, to eliminate or at least reduce the distorting effects of time differences in the comparison of production in different ponds.

Since there is a significant correlation between the number of days of growth and the total weight of fish produced per acre, one may reduce the effect of time differences by calculating the gain in weight per acre per day (the total weight of fish produced divided by the number of days of growth). With this figure one is enabled to compare production from all sources directly with each other. The gain in weight per acre per day is shown in Column 3, Tables 2 to 4.

To make an accurate estimate of the significance of differences between the gain in weight of fish per acre per day and the value of one fertilizer over the other for the production of fingerling bass, the mean gain in weight per acre per day was determined for each fertilizer. Methods have been worked out by various authors for determining the significance of the means of small samples. The method used here is that of Paterson[2] (1939). In Table 5 is shown the means and devia-

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[2] $\sigma_A = \sqrt{\frac{D^2}{\text{Mean deviation}}}$

Standard error of a: $E_A = \sqrt{\frac{\sigma_A}{\text{Number of variates}}}$.

Standard error of difference between means: $E_D = \sqrt{(E_A)^2 + (E_B)^2}$

Difference between means: $D = \bar{A} - \bar{B}$

D/E_D = value of t

Probability can be obtained directly from Fisher's (1936) table of t. The significance of the difference in means may also be roughly determined by referring to the number of degrees of freedom ($N - 2$) in the table for t as determined in this manner and multiplied by E_D. This equals the value above which the difference in means must be to be significant.

tion from the means and other data from which the significance of mean gain in weight per acre per day for each fertilizer was determined.

According to the values of "*t*" calculated from the data in Table 5, the difference in mean weight of fish produced per acre per day with different fertilizers is not significant. The difference between production with cottonseed meal and inorganic fertilizer yielded a probability of 80 to 90 per cent and between organic fertilizer and cottonseed meal a probability of almost 80 per cent.

Table 5.—Mean production per acre per day of largemouth black bass with various fertilizers

Fertilizer	Number of samples	Gain in weight per acre per day	Sum of deviations from mean	$(\text{Deviations})^2$	Percentage of survival
Cottonseed meal......	11	1.19	2.25	30.7	80
Inorganic[1]	5	1.07	0.66	0.43	58
Inorganic[2]	1	1.34	......	......	98
Organic	3	1.05	0.22	0.08	87

[1]With a water bloom. Amount of nitrogen used high.
[2]Without a water bloom. Nitrogen equivalent to organic fertilizers.

Although the fertilizers do produce comparable results when compared on a basis of pounds produced per acre per day, it will be noted (Column 6, Table 5) that from a fish-cultural standpoint the survival was not satisfying with inorganic fertilizer when a water bloom was produced. The one pond fertilized with inorganic fertilizer on the basis of an equal amount of nitrogen to that supplied with organic fertilizers, yielded a survival of 98 per cent which may be considered highly satisfactory. For all practical purposes the excess nitrogen and fertilizer used in the other ponds fertilized with inorganic salts was wasted.

Use of the Gain in Weight per Acre per Day as a Criterion of Production

During the 1942 season an opportunity was provided for practical testing of the criterion, gain in weight per day. Heretofore all experimental information was collected on one pond unit supplied with water from a spring arising in a limestone formation. The water was of medium hardness and moderately rich in minerals.

Experimental data were collected during the 1942 season on another pond unit supplied with comparatively soft water, low in certain minerals, and bearing some humic acids from swamp run-off. The water was slightly acid and slightly brown. The pond bottoms lacked aquatic vegetation because the ponds had not been used for a number of years.

It was believed that this unit would not prove as productive as that from which previous data had been collected. Such waters may lack

sufficient quantities of minerals such as calcium, phosphorus, and potassium. Therefore, to supplement the cottonseed meal, some ponds were fertilized with lime or colloidal phosphate or with both lime and colloidal phosphate in conjunction with identical amount of meal. All series were set up in triplicate.

The data from these ponds given in Table 6 include the number of largemouth black bass produced per acre, survival, weight per acre, size, and gain in weight per acre per day. Although the ponds were fertilized with the same amount of cottonseed meal as in the experiments discussed previously, and although cottonseed meal was fortified with minerals, the results do not approach those obtained from spring water in the other hatchery unit.

The number of days of growth was about 2 weeks longer than that in spring water (Tables 2, 3, and 4). The number of fingerlings produced per acre (9,366 to 13,153) and the survival (63 to 87 per cent of the fry stocked) were about as high or higher on an average. In these respects the fish-culturist would call the ponds highly successful. On the other hand, although the growing period was longer, both the average length of fingerlings and weight of fish per acre were below the values indicated in the other experimental data. The fingerlings averaged 2.5 inches long and 70 to 80 pounds per acre in spring water, but in the river water the averages were only 2.0 to 2.4 inches and from 40 to 61 pounds per acre.

The gain in weight per acre per day (shown in the sixth column) was calculated for all ponds and averaged for each group of ponds fertilized with the same combination of fertilizers. From a physiological point of view the gain in weight per acre per day takes into consideration the length of growing time and the total weight produced. It ignores the number per acre and survival which may be

Table 6.—Largemouth black bass production in 1942 in ponds at the Old State Unit

Fertilizer	Number per acre	Percentage of survival	Pounds per acre	Days of growth	Gain in weight per acre per day	Average length
Cottonseed meal	11,050	74	43.4	112	0.36	2.08
	8,755	58	33.5	84	0.40	2.18
	8,292	55	38.9	86	0.45	2.24
Average	9,366	62	38.6	94	0.40	2.17
Cottonseed meal and colloidal phosphate	13,503	90	60.6	89	0.68	2.20
	12,508	83	38.2	86	0.44	1.80
	8,445	56	42.8	86	0.50	2.07
Average	11,485	77	47.2	87	0.54	2.03
Cottonseed meal and lime	9,752	65	56.8	84	0.68	2.42
	14,478	97	70.8	84	0.84	2.29
	11,503	77	47.4	85	0.56	2.15
Average	11,911	79	58.3	84	0.69	2.29
Cottonseed meal, lime, and colloidal phosphate	12,177	81	53.4	84	0.64	2.48
	15,147	100	68.7	85	0.81	2.24
	12,135	80	61.6	87	0.70	2.32
Average	13,153	87	61.2	85	0.72	2.35

affected by ecological factors rather than the type of fertilizer used or the chemical content of the water.

To determine the actual importance of the observed differences in mean gain in weight per acre per day, the tests of significance described earlier were applied. These productions recorded in Table 6 were compared with cottonseed meal in spring water. The ratio of the difference between means for ponds of this experiment fertilized with cottonseed meal and those using spring water and fertilized with cottonseed meal, to the error of the differences gave a value of "*t*" which would be encountered between 2 and 5 per cent of the time. This is outside the arbitrary $p = .05$ and may therefore be considered significant.

When the mean for the ponds fertilized with cottonseed meal and colloidal phosphate on the one unit was compared with that of ponds fertilized with cottonseed meal on the spring unit, the value of "*t*" fell near $p = .05$. However, the difference of the means was more than twice the error of the difference of the means. Therefore, the mean value obtained can be considered significantly different.

In the two series fertilized with lime and lime plus colloidal phosphate in conjunction with cottonseed meal, t is equivalent to a value of p between 0.3 and 0.2. Thus these means are not significantly different, although they show a considerable variation from that for ponds using spring water and fertilized with cottonseed meal.

The two groups of ponds, fertilized with cottonseed meal on the one hand and cottonseed meal and colloidal phosphate in the other, yielded mean gains in weight per acre per day whose difference precluded the probability of their being drawn from related experimental data. In the two groups, fertilized with cottonseed meal and lime, and with cottonseed meal, lime and colloidal phosphate, the difference in the mean gain in weight per acre per day could not be considered significant. These data indicate the value of lime in these particular waters.

The fact that the gain in weight per acre per day varied from 0.49 to 0.75 pounds with various combinations indicates that certain elements present in some combinations but absent from others were instrumental in bringing about these differences. The fact that the spring water produced from 0.97 to 1.34 pounds per acre per day indicates that these elements are present in that water. Additional experimental work will be necessary to determine what these substances are.

In these particular waters the value of the use of lime with cottonseed meal is also indicated by the fact that although the gain in weight per acre per day increased 69 per cent when lime was added, lime and phosphorus together increased production only 5 per cent more. However, colloidal phosphate alone increased the effectiveness of cottonseed meal by 34 per cent. Since this phosphate contains about 25 per cent calcium carbonate, and since colloidal phosphate increased the effectiveness of lime and cottonseed meal only 5 per cent, it would be

deduced that much of the effectiveness of the phosphate may have been due to the presence of calcium compounds.

Another series of five ponds in the same unit (with a water supply from the St. Johns River) were set up with five combinations of fertilizer. The results were entirely different from those just described. Since these single ponds were intended merely as trials to indicate further lines of research the evidence cannot be considered as conclusive although it should be considered. The variation of results from apparently similar ponds limits very much the value of data from single ponds for comparative purposes. At least three ponds must be used to derive reliable information. A much larger series is probably desirable.

The ponds were fertilized with hay, hay and colloidal phosphate, hay and lime, hay and nitrate, and hay, nitrate, and colloidal phosphate. The results of the experiments are shown in Table 7.

Table 7.—Largemouth bass production in ponds fertilized with hay

Fertilizer	Percentage of survival	Weight per acre	Days of growth	Gain in weight per acre per day	Average length
Hay	59	35.2	83	0.42	2.11
Hay and lime	79	40.6	85	0.52	2.25
Hay and nitrate	76	46.8	84	0.56	2.14
Hay and colloidal phosphate	54	54.8	85	0.65	2.55
Hay, nitrate, and colloidal phosphate	70	78.5	85	0.76	2.70

Hay was used in these experiments to supply the high carbohydrate-nitrogen ratio necessary for rapid bacteriological activity. The lime and phosphate were supplied to alleviate possible mineral deficiencies, and the nitrate to supply a ready source of nitrogen.

Although there is no indication from the production figures that any of the ponds in these two series of experiments (Tables 6 and 7) was not successful since production was average or above, fluctuations in the gain per acre per day indicate that certain minerals may be more beneficial than others.

In the series described previously it was shown that the colloidal phosphate with cottonseed meal gave poorer results than when cottonseed meal was used in conjunction with lime. In this series the reverse held true: the two ponds with highest production were fertilized with colloidal phosphate in conjunction with hay. In this latter series nitrate helped a little, but in combination with colloidal phosphate it yielded at a much higher rate than where no phosphate was used. Lime increased the productivity of hay only 11 per cent as contrasted to an increase of 69 per cent with cottonseed meal. On the other hand, colloidal phosphate increased productivity of hay 52 per cent as contrasted to 5 per cent with the meal.

The value of different minerals has been demonstrated in conjunc-

tion with two different sources of energy-producing materials with water from the same source. From these two series of ponds the gain in weight per acre per day has been shown to be a fairly sensitive tool for the expression of experimental results as regards the value of various fertilizers in different types of waters or of various combinations of fertilizers in a single type of water. No other measure has given such an accurate basis for the comparison of results.

Similar examples of the value of the gain per acre per day in comparing fish production in the same or different waters in relation to the C/N ratio of the bottom deposits and the nitrogen content of the water during the growing season might be given. However, the significance of its use with regard to different fertilizer combinations and different waters will alone establish its value as a tool for the biologist who is studying fish production as related to fertilizers and foods in various sections of the country. The gain per acre per day allows comparison of data from various sources, which up to now could not be compared because of variations in ecological conditions or the number of days of growth and their resulting effect on fish production.

Literature Cited

Fisher, R. A.
1940. Statistical methods for research workers, 7th Ed., 356 pp. Oliver and Boyd, Edinburgh.

Paterson, D. D.
1939. Statistical technique in agricultural research, 1st Ed., 263 pp., McGraw-Hill Book Co.

Snedecor, George W.
1940. Statistical methods applied to experiments in agriculture and biology. 3rd Ed., 422 pp. Iowa State College Press, Ames.

FIN REGENERATION IN BROWN TROUT

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Abstract

In recent years, fin-clipping has become a widely-used method of distinctively marking fish for future identification.

A check on possible regeneration in this type of marking is desirable. The following paper presents data on the clipping of ventral fins of yearling brown trout for two successive years.

As part of a long-time research study, yearling brown trout stocked in East Koy and Wiscoy Creeks, New York, have been marked by the removal of various fins and combinations of fins.

In the spring of 1941, about 20,000 unsorted yearling brown trout (size range 4 to 10 inches) were marked by the removal of the left ventral fin. Wiss scissors No. 624½ were used. The fish were rendered momentarily comatose by electric shock and the fins cut off as closely as possible to the body of the fish.

Approximately 6,000 of these fish were held at the State Fish Hatchery, Randolph, New York, for a period of about five months at which time they were examined for fin regeneration. These fish were separated into two lots of about 3,000 fish per lot and kept in two separate ponds. A 10% sample from each pond was examined.

In 1942, a similar procedure was followed except the right ventral fin was removed.

After a preliminary examination of these fish, an arbitrary classification of categories was set up which seemed to fit the various types and degrees of fin regeneration. Table 1 presents a summary of these data.

From the above data, it is evident, despite many types and degrees of fin regeneration, that complete, normal regeneration is so rare that the clipping of the ventral fins may be considered an effective method of marking brown trout of this size and age for future identification. Checks over a longer period of time and of other fins are desirable and are in progress.

The writer is indebted to Dr. W. C. Senning for assistance in establishing the classification categories and to Mr. Clair Phillips, foreman, State Fish Hatchery, Randolph, New York, for supervising the care of the fish while being held at the hatchery.

Table 1.—Condition of clipped ventral fins on yearling brown trout held at State Fish Hatchery, Randolph, New York, 1941[1] and 1942[2]

	Pond A		Pond B		Total Number of Ponds A and B		Percentage in each classification	
Condition of fin	**1941**	**1942**	**1941**	**1942**	**1941**	**1942**	**1941**	**1942**
1. No fin regeneration (nothing more than a small hump with no fin rays)	102	105	69	89	171	194	28.0	32.2
2. Malformed fins with crooked or fused rays. Spike-shaped or broad or growing at an abnormal angle	137	133	166	130	303	263	49.7	43.7
3. Spike-shaped fins with three or less straight, separated rays	29	26	23	36	52	62	8.5	10.3
4. Miniature, well-formed fins with four or more straight, separated rays:								
A. About one-quarter as long as other ventral fin	33	3	30	19	63	22	10.3	3.7
B. About one-half as long as other ventral fin	6	22	11	12	17	34	3.0	5.6
C. About three-quarters as long as other ventral fin	2	13	1	13	3	26	0.5	4.3
D. Fully as long as other ventral fin	0	0	0	1	0	1	0.0	0.2
Total	309	302	300	300	609	602	100.0	100.0

[1]1941—Left ventral removed; clipped—April 1-4; examined—August 26.

[2]1942—Right ventral removed; clipped—March 23-28; examined—September 8.

Two lots of fish (approximately 3,000 per pond) were saved each year. A 10% sample (about 300 fish per pond) was examined each year.

OBSERVATIONS ON THE NATURAL AND ARTIFICIAL PROPAGATION OF THE SMALLMOUTH BLACK BASS, *MICROPTERUS DOLOMIEU*

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ABSTRACT

Counts of smallmouth black bass nests in the same sections of the South Branch of the Potomac, the Cacapon, and the Shenandoah Rivers are reported over a period of several seasons. The 4-year record for the South Branch of the Potomac indicates little change in the smallmouth black bass population. The number of nests varied between 50.7 and 73.2 and averaged 58.1 for each mile of stream. The results of fry counts from wild nests showed an average of 2,159 fry in each nest in the South Branch of the Potomac, 2,210 in the Cacapon River, and 1,998 in the Shenandoah River.

One important characteristic of natural propagation in these rivers is the simultaneous occurrence of spawning in any section of stream having similar conditions. Evidence is supplied to support the theory that a long, drawn-out spawning season in artificial ponds is due to annoyance of the brood fish. The importance of attendance by the male fish at the nest is pointed out.

Examples in pond culture are given to demonstrate that there are other factors involved in the spawning of smallmouth black bass besides temperature. These factors are annoyance, over-crowding of the brood fish, and lack of provision for greater individual privacy among the brood bass during their spawning season. In general, productivity of fry apparently increases with age and size of the brood fish.

INTRODUCTION

This article has two main objectives. One is to show that spawning of the smallmouth black bass, *Micropterus dolomieu* Lacépède, in streams of the Potomac River watershed occurs simultaneously in any section with uniform conditions. Almost all female fish capable of spawning deposit their eggs within a few days after the water reaches the proper temperature. Few stragglers occur among wild spawning fish.

Observations, made intermittently over a 6-year period, on the natural propagation of smallmouth black bass in certain sections of the South Branch of the Potomac River near Romney, the Cacapon River near Largent, West Virginia, the main stream of the Shenandoah River near Berryville and its North Fork near Strasburg, Virginia, are recorded. A comparison was made of these streams in an earlier paper (Surber, 1939). The reader is referred to this paper for a description of the streams alluded to in this report.

The second objective, and the most important from the standpoint of the improvement of fish-cultural practices, is to demonstrate that spawning in artificial ponds during successive rises in temperature and over long periods of time is neither natural nor conducive to produc-

tion. Spawning over long periods can be largely eliminated by giving the brood bass maximum individual privacy during the spawning season.

Beeman (1924) states, "In our 22 years' experience our greatest difficulty has been in getting enough fry." Langlois (1931, 1933) described and recommended a system of continuous stalls along the shores of brood stock ponds which made removal of fry convenient, but a study of his data reveals a low average production of fry for each brood fish. In addition, he records trouble with refanning of nests. Another bad feature of the method is that it crowds a large number of fish of a species very susceptible to some of the most dreaded diseases. Such protozan parasites as *Ichthyopthirius multifilis* and *Trichophrya micropteri,* the latter described by Davis (1937), may be particularly destructive to smallmouth black bass just preceding and during the spawning season. Davis has since observed (unpublished) that bacterial gill disease (described by Davis, 1926) may also destroy these fish when held together in relatively small quarters during the winter or early spring when water temperatures are low.

While all bass did not spawn in the hatchery ponds at one time in

Table 1.—Extent of natural propagation in three rivers of the Potomac watershed

Item	South Branch of Potomac River				
	1936	1937	1938-I[2]	1938-II[3]	1941
Length of section surveyed	2.8	2.8	2.8	2.8	2.8
Number of nests in each mile	50.7	73.2	55.4	....	53.2
Number of nests containing eggs	72(50.7)[1]	170(82.9)	14(9.0)	0(0.0)	114(76.5)
Number of nests containing fry	0(0.0)	18(8.8)	135(87.1)	33(97.1)	21(14.1)
Number of nests without eggs or fry	70(49.3)	17(8.3)	6(3.9)	1(2.9)	14(9.4)
Average depth of nests (inches)	31.3	33.2	27.5	18.5	....
Date of observations	May 1, 2	May 14, 15	May 2	June 14	May 3
Temperature (° F.)	65.5	68	69	77	....

1942, it is believed that considerable progress has been made in the solution of the problem of obtaining maximum fry production. Although temperature is an important factor in activating the spawning of the smallmouth black bass, it is now obvious that there are other essential requisites to successful spawning.

The writer acknowledges with gratitude long hours of overtime assistance by the following members or former members of the staff of the Leetown station in counting individually the fry removed from the bass nests listed in this report: George E. Klak, Bartlett Hazen, John F. Gardner, Reuben O. Knuth, Robert H. Graham, and Elmer Aikens. The suggestions of Dr. H. S. Davis, in charge of Aquicultural Investigations, particularly in the preparation of this paper, are appreciated.

Time and Extent of Natural Propagation in Rivers

The extent of natural propagation in four Appalachian mountain streams has been determined quantitatively by counting nests over a convenient length of stream, in this study 2.8 to 4.8 miles. Observa-

tions were made by drifting or paddling downstream in a canoe over the nesting areas. Nests were seldom located where there was any perceptible current, and gravel beds or gravel bottoms within 15 feet of the bank were utilized almost invariably. Only a few nests were found on bedrock and these often had a few stones in their centers. Gravelly areas near overhanging bushes or beneath slender sticks or small limbs were favorite places. Large submerged logs were for some reason avoided. Proper bottom materials within 15 feet of the bank seemed to be the principal requirement. Table 1 gives the results of counts of smallmouth black bass nests, the condition of the nests as regards the presence of eggs or fry, and the average depth. Average depth was not determined during all seasons, but sufficient data were collected to indicate that the annual variations in average depth in a stream like the South Branch of the Potomac River were due to variations in the water level which recedes as the season advances. For example, the average depth of nests for the second spawning of 1938 (Table 1, Column 1938-II) in the South Branch of the Potomac River was only 18.5 inches as compared to an average depth of 27.5 inches during the first spawning. Nests with fry predominating are usually at shallower depths than nests with eggs. The Shenandoah River during the spring ordinarily is cloudy with silt. In 1936, this river was too cloudy for an accurate count of nests during the spawning season.

Table 1.—*Continued.*

Shenandoah River				Cacapon River			
1937	1938	1939	1941	1937	1938-I	1938-II	1941
3.8	3.8	3.8	3.8	4.8	4.8	....	4.8
11.0	10.9	30.0	21.6	17.5	44.2	....	41.3
15(88.2)	26(63.4)	32(56.1)	18(43.9)	17(40.5)	68(64.8)	8(12.7)	74(74.7)
1(5.9)	5(12.2)	19(33.3)	13(31.7)	0(0.0)	2(1.8)	47(74.6)	16(16.2)
1(5.9)	10(24.4)	6(10.5)	10(24.4)	25(59.5)	35(33.3)	8(12.7)	9(9.1)
29.3	22.4	....	....	....	25.6	24.6	....
May 12	April 29	May 8, 9	May 1	May 11	April 28	June 10	May 2
68	71	....	....	60.5	67.0	75.0	....

[1]Number in parenthesis is the percentage of total nests observed.
[2]First spawning.
[3]Second spawning.

The South Branch of the Potomac River has the most ideal nesting conditions of all streams yet observed, and an examination of the data for this stream illustrates the simultaneousness of successful spawning. Most of the spawning occurs within a 3-or 4-day period or even less. In 1937, on the days of the counts (May 14-15), 82.9 per cent of all nests contained eggs. In the first spawning of 1938, the river was visited on May 2, and by that time 87.1 per cent of the nests held fry. Heavy showers caused a sudden rise in the river shortly after this count was made, and the fry were completely destroyed, as far as could be determined. This rise in river level was followed by a second spawning of considerable consequence. This second spawning, unusual in this section, occurred after a month of cold weather, and amounted to only about one-fourth of the principal spawning. It had

the same characteristic of simultaneousness, however, for 97.1 per cent of the nests contained fry on June 14, the latest date bass have been seen over their nests in this region. In 1941, 76.5 per cent of the nests contained eggs on May 3, and the fry in them were almost ready to rise by May 8. In the Cacapon River in 1941, 74.7 per cent of the nests contained eggs on May 2, and by May 6, many of the nests held black fry. From these observations, it is evident that the spawning season arrives and passes swiftly under natural conditions in this region.

NUMBER OF FRY PRODUCED UNDER NATURAL CONDITIONS

In 1938, the number of fry in 16 nests from the "test stream" sections was determined by collecting the fry with a 12-quart pail (Fig. 1) in the bottom center of which was soldered a piece of three-quarter-inch galvanized pipe, 2 inches in length, threaded at the end. A piece of three-quarter-inch garden hose, about 2 feet long, was attached to the threaded end. This apparatus for collecting fry was devised by

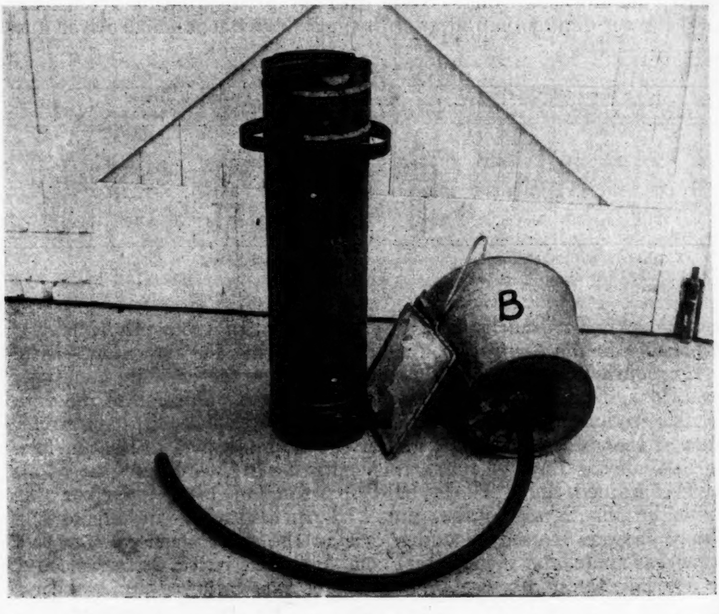

Figure 1.—Apparatus used in study of bass nests. (A) Tube with magnifying glass in bottom for close examination of nests. (B) Pail with siphon hose attached for collecting fry.

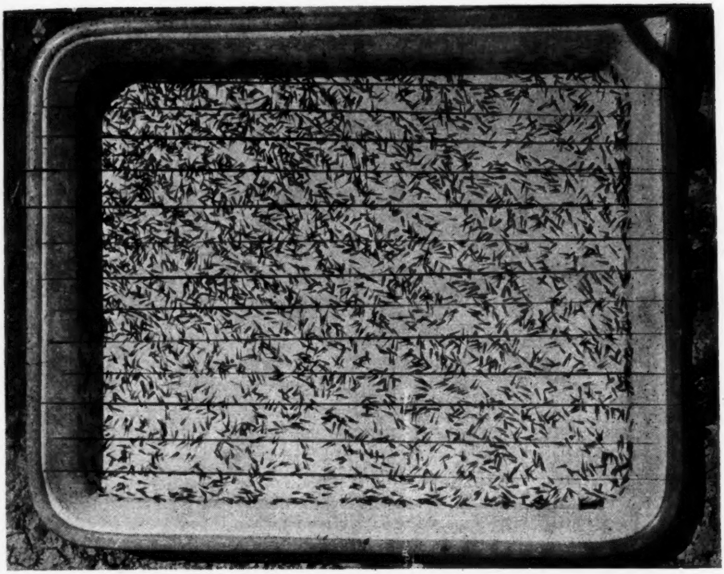

Figure 2.—Smallmouth black bass fry photographed in white enamelled pan for purpose of enumeration.

Albert M. Powell, of the Maryland Conservation Department, and given to the writer. In collecting the fry for these counts, the pail was thrust into the water with the finger-tips of the left hand while the right hand directed the tip of the suction hose. Fry were collected very effectively and without injury by this method. The collected fry were then placed in a white enamelled pan and photographed (Fig. 2) at the stream site or placed in pails and counted later.

The younger bass fry collected before they had become jet black showed a tendency to collect together immediately in schools when placed in a white enamelled pan (Fig. 3), while the older fry, with yolk sacs nearly absorbed, distributed themselves uniformly throughout the pan. The newly-hatched, nearly transparent fry exhibit a negative phototropism or gregariousness that gradually diminishes as the fry grow older. Table 2 presents the data on individual nests.

In 1941, a comparison was made of fry produced by bass in three of the rivers under observation. The results of this study are summarized in Table 3.

The average number of fry in each nest was determined for the

South Branch of the Potomac during 1941. This number (2,036) was somewhat under the figure for 1938 (2,338 per nest) but close enough to indicate that the average nest produces at least 2,000 fry (2,159).

On May 2, 1941, six large deep nests attended by males up to about 18 inches in length were picked up in the Cacapon River test section. These large nests averaged 5,654 fry in each nest. On May 9, 1941, the number of fry in 22 nests collected in the poorest part of the test section on the Cacapon River was determined. These nests averaged only 1,043 fry each and were generally in shallow water attended by small males. The general average for Cacapon River nests during 1941 was 2,210 fry.

It has been interesting to note that nests in this river are usually at shallower depths than nests in the other two clearer streams.

Table 2.—Number of fry per nest (photographic method)

Nest No.	Number of fry photographed	Fry left in nest	Total fry in each nest	Remarks
First Spawning—South Branch of the Potomac River—May 3, 1938				
1	1,577	20	1,597	Used suction pail
2	2,397	79	2,476	Used suction pail
3	2,927	221	3,148	Suction pail only
4	2,369	156	2,525	Used dip net
5	2,501	200	2,701	Suction pail—finished with net
6	1,468	57	1,525	Suction pail
7	1,660	57	1,717	Suction pail
8	2,788	127	2,915	Suction pail
9	2,199	154	2,353	Suction pail only
10	2,743	75	2,818	Suction pail and dip net
11	1,868	73	1,941	Used suction pail and dip net
Average number of fry per nest			2,338	
Second Spawning—South Branch of the Potomac River—June 14, 1938				
1	689	25	714	
2	1,361	76	1,437	
Average number of fry per nest			1,076	
Second Spawning only—Cacapon River—June 10, 1938				
1	723	160	883	
2	988	59	1,047	
3	1,016	61	1,077	
Average number of fry in each nest			1,002	

Production of Fry in Artificial Ponds

In 1939, a detailed record was kept of all fry produced in our spawning ponds as well as a continuous record of water temperatures (Fig. 4.) The temperature record for pond C-4 is furnished to illustrate the fact that there may be other factors besides temperature involved in the production of smallmouth black bass fry. One of these factors, and probably a very important one, is disturbance of the nesting fishes by going about the spawning ponds in search of nests. Reighard (1905) recognized this factor and examined it, on a small scale, with respect to egg and young fry losses.

Desertions were particularly noticeable in our ponds in 1941. The success of a nest, both in rivers and artificial ponds, is believed to be

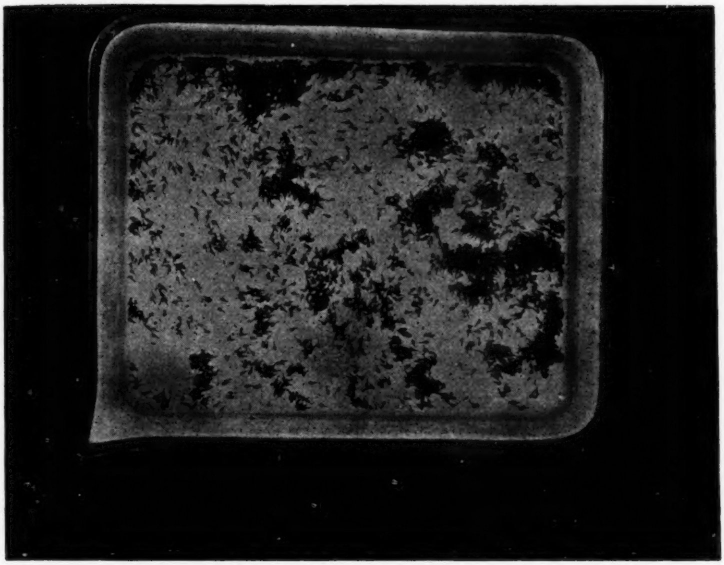

Figure 3.—Smallmouth black bass sac fry.

vitally dependent upon the attendance of the male fish. If a male deserts its nest, the eggs or fry may be quickly eaten by other bass, minnows, or other egg and fry predators.

In 1939, fry were removed from the ponds, beginning May 10, and ending May 20. In pond C-8, of 3-year-old hatchery-reared bass, most of the brood stock apparently spawned simultaneously since 77.8 per cent of all fry produced were removed on one day (May 18). In pond C-2, containing 38 large wild fish over 15 inches in length, 63.0 per cent of the fry were produced May 10, 11. In the remaining pond, C-4, with 122 brood fish of wild stock, 59.8 per cent of the fry were removed on May 10, 11. There was evidence of a second spawning following the probable let-up in our activity about the ponds on May 10, 11. The temperature record for pond C-4 taken during 1939 (Fig. 4) shows a drop in pond temperatures to a minimum of 55.5°F. on May 14. The second period of fry productivity could not have followed the second rise in temperature because there was insufficient time intervening for incubation of the eggs. Instances where eggs have been deposited and the resulting fry have risen from their nests within a 5-day period have been recorded, but it seems likely that the

Table 3.—Comparison of fry produced by smallmouth black bass in three rivers, 1941

Name of river	Date	Number of nests	Total number of fry	Average number of fry in each nest
South Branch of the Potomac	May 8	16	32,577	2,036
Shenandoah River	May 7	7	13,983	1,998
Cacapon River (Largent)	May 2	6[1]	33,922	5,654
Cacapon River (Cacapon Bridge)	May 6	9	22,656	2,517
Cacapon River (near Largent)	May 9	22	22,954	1,043
Cacapon River (near Largent)	May 14	10[2]	24,360	2,436

[1]These nests were collected because of their large size. They are usually nests in the deeper water.

[2]Taken from a poor nesting section.

second spawning in this case occurred before the temperature drop illustrated in Figure 4, and that it coincided with diminished activity in removing the first batch of fry from the ponds.

On one occasion in 1941, ten nests with eggs were counted in this pond, but two days later, only four contained fry. In this case, activity by persons about the pond no doubt caused desertions which were disastrous to those nests. Nests were repeatedly refanned and one bass was observed eating fry in a deserted nest, by Bartlett Hazen of the Leetown staff.

From this example in the artificial pond culture of smallmouth black bass, and the knowledge derived from observations on natural propagation, it seems that something still may be learned regarding the successful production of fry in artificial ponds. At Leetown in 1939, 38 large bass over 15 inches long (16 males, 22 females) in a pond of 0.57 acre in area produced almost as many bass fry (70,225) as a pond

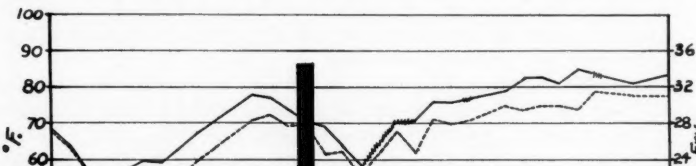

Figure 4.—Maximum and minimum water temperature and smallmouth black bass fry production records for Pond C-4, 1939.

1.7 acres in area with 122 bass (number of fry, 78,614). There is evidence at hand that the proper number of smallmouth black bass to use for each acre requires additional study, particularly in the "Ohio" method described by Langlois (1932). Langlois, himself, concluded that not more than 500 brood bass for each acre should be used in the stall system. At the Maryland State Hatchery, where this system has been employed for the last 5 years, Mr. Albert Powell, Superintendent, has cooperated closely with the writer in comparing notes on fry production. Within the 5-year period from 1937 to 1942, he used from 500 to 1,161 adults for each acre, and, in all years, the number of successful nests has been small. In 1937, 42.1 per cent of the brood bass (sexes undetermined) produced nests, but only 35 per cent of those nests produced fry; in 1938, 40 per cent of the brood bass spawned, but only 18 out of 45 nests (45 per cent) were successful; in 1939, 27.6 per cent of the brood stock produced 78 nests with eggs, but again only 25 nests out of 78 (32 per cent) were successful; in 1941, when the maximum number of brood bass for each acre (1,161) were used, only 6.8 per cent of the 325 brood bass produced nests; again in 1942, when 829 bass for each acre were used, 32.3 per cent of the brood bass produced nests, but again many nests were not successful.

The experience in ponds at Leetown tends to confirm Lydell's (1926) conclusion that not more than 150 brood bass for each acre should be used.

Eliminating the Annoyance Factor

It was during 1941, a poor season, that the writer realized fully that human annoyance was the principal factor in preventing simultaneous and really successful spawning by our smallmouth black bass brood stock.

Plans were made to test the theory during 1942. All precautions possible were taken to prevent the disturbance of the bass during the spawning season.

Pond K-1 (0.48 acre) was stocked with 150 bass for each acre. The 72 fish placed in it included 32 male and 40 female fish which had been fed on artificial food during the summer and live minnows through the winter. These large fish ranged from about 11 to 20.5 inches in length. Among them were some wild fish collected during 1941.

Pond F-2 (0.3 acre) was stocked with 23 fine, large domestic fish reared from fry hatched in 1936. These fish ranged in length from 12.1 to 17.0 inches (average 13.9) and included 10 males and 13 females.

Pond I-8 (0.35 acre) was stocked with 20 male and 29 female wild fish under 10 inches in length.

The only visits made to these ponds after stocking them early in April were for the purpose of adding quantities of minnows sufficient to keep them well supplied with food. Artificial food might have been

Table 4.—Summary of smallmouth black bass fry production in ponds at Leetown, 1942

Item	Pond I-8		Pond K-1		Pond F-2	
	Spawning I	Spawning II	Spawning I	Spawning II.	Spawning I	Spawning II
Number of males in pond	20	20	32	32	10	10
Number of females in pond	29	29	40	40	13	13
Number of nests provided	19	19	29	29	19	19
Number of nests unused	3	18	3	20	11	14
Percentage of females spawning	55.2	3.4	65.0	22.5	61.5	38.5
Total number of fry	27,727	?	126,796	45,570	60,088	18,661
Average number of fry in each nest containing them	1,733	....	4,877	5,063	7,511	3,732
Date of spawning	April 16, 17	....	April 16, 17	May 11	April 15, 16	May 11
Date of removal of fry	May 6, 8	....	May 4-8	May 22, 23	May 2-6	May 19, 21, 22

fed to the fish in ponds K-1 and F-2, but live minnows were added because they could scatter themselves (or be scattered by the fish) throughout the pond without disturbance of nesting fish.

Another precaution was to place the gravel nests only along the shore line. This made the use of a boat to view the nests unnecessary.

That the precautions taken produced successful results can be determined by an inspection of Tables 4 and 5, which give all pertinent information. The bass fry removed from every nest were counted by hand.

The following facts are illustrated by these data: (1) All ripe female brood bass (in ponds K-1 and F-2) which were ready to spawn by mid-April spawned simultaneously as they do under natural conditions. With the exception of one fish, all of the wild females in pond I-8 spawned at one time. (2) A second spawning period occurred in ponds K-1 and F-2 on or after May 8. It was interesting to note that this spawning period might have occurred earlier had temperature been the all-important factor. A study of a continuous temperature record for pond K-1 during the spawning season showed a rapid rise in the water temperature from 61° F. on April 28 to 76° F. on May 1. This rise in temperature did not iniate spawning. Another rise in temperature occurred on May 5 and 6 when the water temperature rose from 65° F. on May 5 to 78° F. on May 6. New nests with eggs did not appear at the time, undoubtedly because the fish were disturbed by the activity of men about the pond in the collection of fry from the first spawning period. It is true that a second spawning period was associated with a wide fluctuation in temperature from 57.5° F. to 77° F. on May 11, but the restoration of quietness after May 8 gave the fish the privacy required for successful spawning. (3) In spawning, the female fish spawned out completely and did not produce dribbles of eggs at intervals on successive rises in temperature. The best proof for this is from pond F-2, where 13 females were stocked and 13 spawned. One of these females evidently started to spawn in Nest No. 4, but finished in No. 5, from which 12,249 fry were removed. Other proof is provided by pond K-1, where the average number of fry in each nest in Spawning II (average, 5,063 fry each) is greater than in Spawning I (average, 4,877 fry each). (4) There has been no evidence, thus far, that old age has any adverse effect on fry production. The bass in pond F-2, now in their seventh season, are getting more productive each year. (5) Bass under 10 inches in length are unlikely to produce more than 3,000 young fish. More information of this type may be of value in field observations in streams where it is desired to obtain some idea of the ratio of undersized to legal-sized fish.

The writer made a special trip to the "test sections" of the South Branch of the Potomac and Cacapon Rivers on May 15, 1942, to determine whether a second spawning of consequence had occurred in the rivers as in the hatchery ponds. The principal spawning areas were covered in the 2.75 mile length section of the South Branch of the Po-

Table 5.—Production of smallmouth black bass fry in ponds at Leetown, 1942

Pond I-8				Pond K-1				Pond F-2			
Spawning I		Spawning II		Spawning I		Spawning II		Spawning I		Spawning II	
Nest No.	Number of fry removed	Nest No.	Number of fry removed	Nest No.	Number of fry removed	Nest No.	Number of fry removed	Nest No.	Number of fry removed	Nest No.	Number of fry removed
1	477	13	Fry risen	1	9,150	1	2,700	4	472	7	4,293
2	1,941	....	and scat-	2	2,469	4	4,545	5	12,249	8	1,885
3	3,387	....	tered when	3	6,936	10	5,324	8	6,529	9	4,477
5	943	....	observed.	4	890	11	8,246	9	6,181	12	5,287
6	2,799	....	Large nest.	5	5,040	13	5,350	13	8,654	18	2,719
7	2,872	....	......	6	5,988	16	2,563	14	7,455	....	......
8	462	....	......	7	3,023	18	4,854	15	7,819	....	......
10	816	....	......	8	173	26	9,001	18	10,729	....	......
11	2,210	....	......	9	5,403	27	2,987	....	......	....	......
12	2,198	....	......	10	7,100	....	......	....	......	....	......
13	2,145	....	......	11	3,138	....	......	....	......	....	......
14	606	....	......	12	3,075	....	......	....	......	....	......
15	290	....	......	13	11,369	....	......	....	......	....	......
17	2,364	....	......	14	4,551	....	......	....	......	....	......
18	1,160	....	......	15	4,839	....	......	....	......	....	......
19	3,057	....	......	16	5,134	....	......	....	......	....	......
....	......	....	......	17	7,957	....	......	....	......	....	......
....	......	....	......	18	6,250	....	......	....	......	....	......
....	......	....	......	19	152	....	......	....	......	....	......
....	......	....	......	20	3,974	....	......	....	......	....	......
....	......	....	......	22	154	....	......	....	......	....	......
....	......	....	......	23	10,124	....	......	....	......	....	......
....	......	....	......	25	472	....	......	....	......	....	......
....	......	....	......	27	5,468	....	......	....	......	....	......
....	......	....	......	28	6,571	....	......	....	......	....	......
....	......	....	......	29	7,396	....	......	....	......	....	......

tomac with the discovery of a single nest with eggs. Here, as in the Cacapon River, most of the fry had risen from their nests on May 7 and 8. Time permitted the survey of only a mile section of the Cacapon River on this same day (May 15). The section was a very long pool near Largent, W. Va. A total of thirty-two nests were found. In the vicinity of nineteen nests, scattered fry could still be found. Eleven nests were without fry or eggs, and only two fresh nests were found with eggs. It was evident, as recorded in previous years, that the first spawning was the most important, and was simultaneous in nature.

Literature Cited

Beeman, Henry W.
1924. Habits and propagation of the smallmouthed black bass. Trans Am. Fish. Soc., Vol. 54, pp. 92-107.

Davis, H. S.
1926. A new gill disease of trout. Trans. Am. Fish. Soc., Vol. 56, pp. 156-159.
1937. A gill disease of the smallmouth black bass. The Progressive Fish-Culturist. No. 27, February 1937, pp. 7-11.

Langlois, T. H.
1931. The problem of efficient management of hatcheries used for the production of pond fishes. Trans. Am. Soc., Vol. 61, pp. 106-115.
1933. Problems of pondfish culture. Trans. Am. Fish. Soc., Vol. 62, 1932, pp. 156-166.

Lydell, Dwight
1926. Smallmouthed bass propagation. Trans. Am. Fish. Soc., Vol. 56, pp. 43-46.

Reighard, Jacob
1905. The breeding habits, development and propagation of the black bass. Bull. Mich. Fish. Comm., No. 7 (from 16th Bien. Rep. St. Bd. Fish Comm., 1903-04), pp. 1-73.

Surber, Eugene W.
1939. A comparison of four eastern smallmouth bass streams. Trans. Am. Fish. Soc., Vol. 68, 1938, pp. 322-335.

THE MEASUREMENT OF FISHING INTENSITY ON THE LOWER T.V.A. RESERVOIRS[1]

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ABSTRACT

In March 1940, an intensive inventory of fishing on the lower T.V.A. reservoirs was undertaken to determine the extent and value of their fishery. Since only two outboard motorboats were used in this census and since the four lower reservoirs have a combined shoreline of some 2,600 miles, it was necessary to divide them into sections which could be covered in one day and to develop sampling techniques for the study. At first, periodic sampling was used, but in August this method was abandoned in favor of stratified random sampling. During the period of the study 123 complete counts were made and a total of over 70,000 miles of shoreline were covered. On the basis of the counts made it was calculated that there were over 1,200,000 man-days of fishing on these reservoirs during the year of the study. About 162,000 man-days of this fishing were concentrated in the small tail-water areas of Guntersville, Wheeler, Wilson, and Pickwick Dams. Fishing was heaviest during April, May, and June, after which it declined steadily to a low in December or February. Bank fishermen were predominant on the reservoirs proper but boat fishermen were dominant in the tail-water areas below the dams with the exception of Pickwick dam. Of the three lower reservoirs fishing was heaviest on Wheeler which had 6.4 fishermen-days per acre. Wilson ranked second with 4.9 fishermen-days, and Pickwick third with 3.3 fishermen-days per acre. The intensity of fishing per mile of shoreline varied from 566 fisherman-days on Wilson Reservoir to 311 on Pickwick Reservoir.

INTRODUCTION

In March 1940, the Biological Readjustment Division of the Tennessee Valley Authority began an extensive inventory of fishing on the lower T.V.A. reservoirs: Guntersville, Wheeler, Wilson, and Pickwick. This study had for its purpose the determination of fishing intensity and its variations on these waters throughout the year, as well as the economic importance of fishing in these impoundments. During the year of the study 123 complete counts of the fishermen on the reservoirs were made. The number of times the entire shoreline of each reservoir was covered is as follows: Guntersville, 8; Wheeler, 30; Wilson, 29; and Pickwick, 56. Several areas near centers of population were visited at more frequent intervals (were covered 6 to 10 additional times). In all, observations were made along over 70,000 miles of shoreline in the inventorying of these four waters.

General observations made during the course of the fishery investigations on the lower reservoirs had suggested that fishing was relatively light the first year of impoundment, that it increased decidedly the second year, that it was heaviest near centers of population and in

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the tail waters below the dams, and that fishing was more extensive after impoundment. These observations, however, did not furnish information on the total amount of fishing or on the intensity per unit area. Furthermore, counts of fishermen made in limited areas were unsatisfactory for estimating the total amount of fishing in the reservoirs due to the size of these waters and the great variability in the concentration of fishing. It was therefore considered necessary to make periodic counts of the fishermen in all parts of the reservoirs in order to obtain reasonably exact information on the total fishing. As the lower reservoirs have a combined shoreline of over 2,600 miles, such counts represented a considerable undertaking. Area, length of shoreline and the volume of the lower reservoirs are shown in Table 1.

Table 1.—Comparison of lower T.V.A. reservoirs

Reservoir	Date of impoundment	Length (miles)	Area (acres)	Miles of shoreline	Greatest depth (feet)	Volume (acre feet)
Guntersville	1-12-39	82.1	70,700	970	55	981,000
Wheeler	9- -36	74.1	68,300	1,063	50	1,115,000
Wilson	4-14-24	15.5	15,500	135	85	600,000
Pickwick	2- 8-38	52.7	46,800	496	72	1,032,000
Total	....	224.4	201,300	2,664	....	3,728,000

Sampling Methods

In planning the study consideration was given to the possibility of using an airplane, but this idea was abandoned in favor of two fast outboard motorboats operating from the Biological Readjustment Division laboratory boat. For convenience in counting and recording the data, the reservoirs were divided into sections, two or more of which were covered within a day's time. In making the counts, the laboratory boat was taken to a central point for the sections to be counted, and the outboard boats worked out from it in each direction. Field glasses were used to locate fishermen in stumpy, backwater areas where the boats could not go near the shore. Stumpy areas in tributary streams were visited by car and counts were made from the bank. Bank and boat fishermen were tabulated separately on a special form. Date, day of the week, number of the section counted, time of day, weather, and the opinion of the census taker as to the kind of fishing day, namely, poor, fair or good were recorded on these forms. Due to the extent of the shoreline, several days were required to make a complete circuit of the reservoirs and it was possible to cover each area only once during a period of several days. The problem of securing a representative sample of the fishing in each area, therefore, presented itself. Because fishing intensity appeared to follow a weekly cycle in the first part of the season, being heaviest on week ends, holidays, and Thursday afternoons (many business establishments close on Thursday afternoon), counts were made in the same area for 7 successive days. By this method it was planned to gain an idea of the total fishing in the weekly cycle and of the percentage of that total for each

day of the week. After this information was acquired, it was planned to make only one count in each area and then use the percentage of fishing represented by the day on which the count was made to calculate the fishing for the week.

After this system was used for a time it became apparent that so much time was consumed in making the weekly counts that the distribution of fishing changed between counts. Also, it became clear that as the season advanced, fishing did not have such a tendency to occur in weekly cycles, and that several factors other than the day of the week influenced the intensity of fishing. It was observed that the type of day exerted more influence on the amount of fishing than did the day of the week. Wind and waves exerted a considerable influence, for on a quiet day fishing was spread out and boat fishermen were found in the open water, while on windy days, when the waves were high, both bank and boat fishermen were confined to sheltered areas.

Furthermore, the condition of the water had some influence, as muddy water and fluctuations in water levels caused fishing to drop off considerably. In addition, the quality of fishing below the dams was influenced by the flow over the spillways. When the flow was moderate fishing was heavy due to the concentration of fish, but when the water was shut off fishing decreased. However, if there was a large flow of water over the spillways the water below the dams was too rough for fishing. It was noted that the negroes did not fish on Saturday afternoon or Sunday and, since they were mostly bank fishermen, this type of fishing was low over the week ends. Boat fishing, however, was intense because the whites who fish mostly on week ends are for the most part boat fishermen. Again, during the cotton-hoeing season, bank fishing was heavy on a day following a rain when it was too wet to work in the fields. Cloudiness and rain exerted a great influence on fishing, but often there were more fishermen on a warm, cloudy, quiet day than on a cold, clear, windy day when the waves were high. Because all these factors tended to disrupt the weekly cycle of fishing, especially after the usual spring enthusiasm had worn off, the periodic method of sampling was abandoned at the end of August in favor of stratified random sampling. It was thought that this type of sampling would be best in view of the many factors influencing the fishing intensity.

In order to permit more frequent sampling, the counts from this time on were confined to the three lower reservoirs—Wheeler, Wilson, and Pickwick. These reservoirs were divided into five sections, each of which could be covered in a day. In order to distribute equally all factors responsible for the variation in fishing intensity, the period over which counts were made was "stratified" by dividing it into 10-day periods during which time a complete count of the three reservoirs was made. In drawing up the schedule for counts, each 10-day period was treated as a unit and the section to be counted and the day it was to be counted were determined by drawing numbers according to a

fixed procedure. A drawing was first made of the section to be counted, then one number was drawn to determine on which of the ten days that section was to be counted. The same procedure was followed for the other four sections, and each day selected was removed from the drawing, as two sections could not be counted on the same day. By following this procedure all three reservoirs were counted once every 10 days and a stratified random sample of the fishing was secured. Counts were made on the day selected regardless of the weather. The 10-day periods were so arranged that three of them occurred each month. Thus, there were three complete counts on each reservoir per month. At the end of March 1941 counts on Wheeler and Wilson Reservoirs were discontinued as the full year of counts was completed at that time. Counts were continued in Pickwick Reservoir until the end of August 1941. As this was the only reservoir being counted more time was available and as many as seven counts were made during a month.

Calculation of the Amount of Fishing

Over the total period of the study the counts in each section were fairly well distributed as to the days of the week. In calculating the total amount of fishing the results of the counts in each section were calculated separately due to the fact the weather was not the same in all sections. The totals for all sections were combined directly to determine the totals for each reservoir. Because of the concentration of fishermen below the dams, the tail-water areas have been considered as separate sections and the counts recorded separately.

Standard errors were computed for several of the counts in each of the sections for April and May and for those made in Pickwick Reservoir in July. The means obtained for these counts had large standard errors that varied from 8 to 100 per cent of the mean. Under ordinary conditions the standard error of the mean number of fishermen for a month in any section would be large, even though all fishermen were counted each day of the month. This is due to the great variability in fishing intensity. The standard error of the mean, therefore, is a measure of the variability of the fishing and not a measure of the accuracy of the counts. As has been pointed out this variability is traceable to several conditions, the most important of which is weather and its associated factors. After a consideration of all factors, it was decided that the classification of each day as a good, fair, or poor fishing day, according to the weather, was the best method to use in calculating the total amount of fishing during any one month.

Before computing the totals, the actual number of fishermen observed in each section was multiplied by two to secure the total number of fishermen in that section for the day. This increase was made because the average fishing time is about 5 hours and fishermen usually fish either in the forenoon or the afternoon. Consequently, the census taker who passed any given point only once a day would see only

about one-half of the anglers fishing in that section during the day. From these records of the counts of fishermen made in one section, or a group of sections, the average number of bank and boat fishermen who were found fishing on each type of fishing day—poor, fair, or good—was determined. The average of the number of fishermen counted on poor fishing days was then multiplied by the number of poor fishing days occurring in that month to determine the fishing for these days. In the same way the average numbers fishing on fair and good days were each multiplied by the numbers of fair and good fishing days occurring in the month and the products for the three types of days added to obtain the calculated total of bank and boat fishing for the month. This procedure was followed, in so far as possible, for each reservoir each month.

When data were not available in one section for one of these three types of fishing days, but were available for an adjacent section, the average for that type of day was determined by proportion. Estimates of fishing intensity, in each reservoir based on the two methods of sampling, are presented in Table 2.

Intensity and Distribution of Fishing

These fishermen counts indicate that fishing on the lower T.V.A. reservoirs is quite heavy on both the old and the new waters. Calculations based on these counts show that during the period of one year there were 665,300 fishermen days of fishing on the three lower reservoirs, distributed as follows: Wheeler, 434,700; Wilson, 76,400; and Pickwick, 154,200. As only eight counts were made on Guntersville Reservoir estimates for that reservoir have been made for only two months—May and August. The calculated fishing was 143,400 fishermen-days for May and 42,200 for August. During April, May, and June angling on Guntersville Reservoir was much heavier than it was on any of the other lower reservoirs. After the fourth of July fishing dropped off so that by August the total fishing was only a fraction of what it had been in the spring months. It is estimated that angling during April and June was about as heavy as it was in May. However, if fishing on Guntersville for the 10 months for which data were not available was only as heavy as that on Wheeler Reservoir the fishing for the year on Guntersville would total 478,600 fishermen-days. On the basis of these calculations, it is estimated that there were about 1,200,000 man-days of fishing on the four lower reservoirs during the year of the counts. On all the reservoirs fishing was heaviest in the spring months, with a gradual reduction in intensity as the season advanced until a minimum was reached in December or February. Anglers were concentrated near centers of populations and in the tailwater areas below the dams. In general, fishing was heavy in the backwaters and flats in the central part of the reservoirs and was light in the open, wide expanses of water in the lower portions of the reservoirs and in the upper portions where the water was within the old banks

Table 2.—Calculated numbers of fishing trips,[1] by months, on the lower TVA reservoirs during one year—1940-1941

Month	Wheeler Reservoir			Wilson Reservoir			Pickwick Reservoir		
	Bank	Boat	Total	Bank	Boat	Total	Bank	Boat	Total
January	3,300	2,200	[2]5,500	800	1,100	[2]1,900	2,800	1,500	[2]4,300
February	1,600	1,300	[2]2,900	300	1,000	[2]1,300	2,800	1,700	[2]4,500
March	11,600	6,000	[2]17,600	1,400	2,600	[2]4,000	5,500	7,100	12,600
April	43,400	19,200	62,600	......	......	9,000	......	......	[2]21,000
May	56,400	28,600	85,000	7,000	12,400	19,400	11,700	9,700	[2]21,400
June	46,000	21,000	67,000	......	......	15,000	7,600	15,000	[2]22,600
July	34,000	18,300	52,300	2,000	2,400	4,400	7,000	6,700	[2]13,700
August	34,900	18,800	53,700	......	......	7,000	8,000	6,400	[2]14,400
September	24,200	10,800	35,000	800	5,400	6,200	7,300	5,700	13,000
October	20,400	12,500	32,900	400	4,700	5,100	9,200	5,900	15,100
November	8,200	5,400	13,600	400	1,200	1,600	3,500	4,300	7,800
December	2,800	3,800	6,600	200	1,300	1,500	2,000	1,800	3,800
Total	286,800	147,900	434,700	13,300	32,100	76,400	67,400	65,800	154,200

[1]Figures rounded off to the nearest hundred.
[2]Counts made in 1941.

of the river and there was some current. Bank fishermen were more numerous than boat fishermen on all of the reservoirs except Wilson, but in the tail-water areas boat fishermen were more abundant with the exception of the Pickwick tail water.

The counts made on Guntersville Reservoir indicate that bank fishermen were very abundant and made up 88 per cent of the total number fishing. This predominance of bank fishermen was due to the great amount of fishing for carp. Until July carp were biting well and large catches were usually made. Fishermen came from surrounding communities within a radius of 30 miles or more and on week ends and in fair weather thousands of people lined the banks fishing with cane pole and worms. After the carp fishing became poor the proportion of boat fishing increased, but still did not make up as large a proportion of the fishing as on the other reservoirs. This situation may be due in part to the fact that Guntersville is the youngest reservoir and did not have as many boats or boat fishermen as some of the older waters.

Counts of the number of boats on each of the lower reservoirs were made in connection with the fishermen counts. A total of 3,042 boats was noted which were distributed as follows: Guntersville, 741; Wheeler, 1,038; Wilson, 633; and Pickwick, 630. Over 95 per cent of these boats were used for fishing. The greatest concentration of boats was on the oldest reservoir, Wilson, where there was an average of 5.0 per mile of shoreline. The numbers of boats per mile of shoreline on the other three reservoirs were: Wheeler, 1.0; Pickwick, 1.3; Guntersville (the newest reservoir), 0.8.

On Wheeler Reservoir bank fishermen were predominant, but not to such an extent as on Guntersville. They made up 66 per cent of the total fishing, and outranked the boat fishermen in each month except December, when there was a large concentration of the latter below Guntersville Dam. Approximately 6.5 per cent of all fishing and 13 per cent of the boat fishing for the entire reservoir occurred in the tail-water area below Guntersville Dam. Bank fishing predominated in the other parts of the reservoir because the large rural population of negroes fished almost entirely from the banks.

In Wilson Reservoir, much of which is bordered by steep, rocky cliffs unfavorable for bank fishing, the situation was reversed and boat fishermen comprised about 70 per cent of the recorded number of fishermen. The heavy fishing in the tail water below Wheeler Dam was chiefly by boat. Fishing in this area made up approximately 39 per cent of the total fishing on Wilson Reservoir. Bank fishing on this reservoir was further restricted by the fact that because here the adjacent land is privately-owned, making access by land to some areas more difficult than on the other waters where the adjoining land is owned by the government.

About 50 per cent of the anglers counted on Pickwick Reservoir

were bank fishermen. Fishermen below Wilson Dam comprised 42 per cent of the total number found on this reservoir.

Fishing in the tail-water areas below the dams differs considerably from that in the reservoirs proper. According to the counts made there were 161,900 fishermen-days of fishing below Guntersville, Wheeler, Wilson, and Pickwick Dams during the year in which counts of fishermen were made. A large part of this fishing was done below Wilson Dam. Below Guntersville and Wheeler Dams most of the fishing was done by boat but below Wilson Dam there were almost as many bank fishermen as boat fishermen, while below Pickwick Dam the bank fishermen predominated. The estimated total amount of fishing below the dams and the number of fishermen for each month are summarized in Table 3.

Of the several tail waters, the one below Wilson Dam supported the most fishing. Here the estimated number of anglers during the year of the count was over 65,000 compared with approximately 30,000 below Wheeler Dam, and 28,300 below Guntersville Dam. There were about 38,700 fishermen-days of fishing below Pickwick Dam during the year of the counts.

The amount of fishing per acre and the intensity of boat and bank fishing in each of the lower reservoirs are listed in Table 4. Wheeler Reservoir, with 6.4 fishermen-days per acre, leads in the amount of fishing, but if the counts had been carried out on Guntersville Reservoir for the same length of time as on Wheeler Reservoir, Guntersville would probably have shown the greater fishing intensity. Bank fishing on this reservoir was especially heavy; records for only two months indicated 166 fishermen per mile of shoreline. Boat fishing was light. Wheeler, in addition to ranking highest among the three lower reservoirs in total fishing per acre was also highest in fishermen days of bank fishing (270 bank fishing trips per mile of shoreline). The intensity of boat fishing was about the same on Wheeler and Wilson Reservoirs, as Wheeler had 2.2 and Wilson 2.1 fishermen-days per acre. Wilson Reservoir ranked low in bank fishermen but was second in the total fishing per acre.

A comparison of the fishing intensity on the lower TVA reservoirs with that of Michigan and Wisconsin lakes indicates that the TVA reservoirs having the heaviest fishing were as intensively fished as the lakes in the North. Eschmeyer (1938) found that during a 4-year period the fishermen-days per acre on Fife Lake varied from 3.5 to 6.6. Hazzard and Eschmeyer (1938) reported an average of approximately seven fishermen-days per acre for 12 lakes in southern Michigan. Frey (1939) estimated a total of 4.2 fishermen-days per acre on Waubesa Lake and 2.2 on Kegonsa Lake, Wisconsin.

Summary

A study to determine the amount and variation of fishing in the lower T.V.A. reservoirs was begun in March 1940. Counts of bank

Table 3.—Calculated number of fishing trips,[1] by months, below TVA dams (in tail-water areas) during one year—1940-1941

Month	Guntersville Dam			Wheeler Dam			Wilson Dam			Pickwick Dam		
	Bank	Boat	Total	Bank	Boat	Total	Bank	Boat	Total	Bank	Boat	Total
January	500	500	[2]1,000	100	500	[2]600	1,400	700	[2]2,100	400	400	[2]800
February	400	600	[2]1,000	100	800	[2]900	1,300	1,000	[2]2,300	800	300	[2]1,100
March	1,800	900	[2]2,700	500	1,600	[2]2,100	2,600	4,200	[2]6,800	1,400	1,100	[2]2,500
April	800	900	1,700	......	......	2,200	3,300	5,700	[2]9,000	......	......	[2]4,000
May	3,000	1,400	4,400	600	4,000	4,600	6,700	4,400	[2]11,100	4,700	3,100	[2]7,800
June	......	2,900	2,900	......	......	3,500	4,000	5,000	9,000	5,800	5,100	[2]10,900
July	......	2,500	2,500	800	1,200	2,000	2,400	2,500	4,900	500	2,100	[2]2,600
August	......	2,700	2,700	500	3,600	4,100	1,800	3,900	5,700	1,100	2,400	[2]3,500
September	700	1,600	2,300	200	3,500	3,700	2,200	2,000	4,200	500	200	700
October	800	2,800	3,600	100	3,800	3,900	2,400	2,000	4,400	1,000	200	1,200
November	300	2,000	2,300	......	1,000	1,000	1,000	2,500	3,500	1,800	600	2,400
December	200	1,000	1,200	200	1,000	1,200	800	1,300	2,100	600	600	1,200
Total	8,500	19,800	28,300	3,100	21,000	29,800	29,900	35,200	65,100	18,600	16,100	38,700

[1]Figures rounded off to the nearest hundred.
[2]Counts made in 1941.

Table 4.—Intensity of fishing on the lower TVA reservoirs for one year

Reservoir	Man-days of fishing per acre	Man-days of boat fishing per acre	Man-days of bank fishing per mile of shoreline	Man-days fishing per mile of shoreline
Wheeler	6.4	2.2	270	409
Wilson	4.9	[1]2.1	[1]99	566
Pickwick	3.3	[2]1.4	[2]136	311

[1]Represents 9 months of fishing.
[2]Represents 11 months of fishing.

and boat fishermen were made along the entire shoreline by means of two fast outboard motorboats. For convenience in counting, the reservoirs were divided into sections which could be covered by these boats in one day. Early in the season periodic samples were taken, but after August stratified random sampling was used. When the counts were made records of weather were kept and each day was classified as a poor, fair, or good fishing day. In calculating the total number of fishermen-days during the month, the average number fishing on each of the three types of fishing days as determined by the census was multiplied by the number of the corresponding type of day occurring in the month and the products were added to obtain the total fishing for the month.

Fishing was most intensive in the spring months and lightest in December or February. It was concentrated near centers of population and in the tail-water areas below the dams, and was lightest in the open-water areas in the lower portion of the reservoirs. Bank fishermen predominated in the reservoir proper, but boat fishermen were most abundant below the dams. It is calculated that there were about 1,200,000 individual fishing trips on the lower reservoirs during the year of the study. About 162,000 of these were in the tail-water areas below Guntersville, Wheeler, Wilson, and Pickwick Dams. Of the three lower reservoirs (Wheeler, Wilson, Pickwick), Wheeler was fished the heaviest with 6.4 fishermen-day per acre; Wilson was second with 4.9 fishermen-days per acre; and Pickwick was third with 3.3 fishermen-days per acre. Wheeler ranked first in bank fishing and Wheeler and Wilson had about the same amount of boat fishing—2.2 and 2.1 fishermen-days per acre. Fishing intensity on the lower reservoirs compares favorably with that on several northern lakes for which records are available.

Acknowledgements

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Literature Cited

Eschmeyer, R. W.
1939. Summary of a four year creel census on Fife Lake, Michigan. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 354-358.

Frey, David G., Hubert Pedracine, and Lawrence Vike.
1939. Results of a summer creel census on Lakes Waubesa and Kegonsa, Wisconsin. Jour. Wildlife Management, Vol. 3, No. 3, pp. 243-254.

Hazzard, A. S., and R. W. Eschmeyer.
1938. Analysis of the fish catch for one year in the Waterloo Project Area. Papers Mich. Acad. Sci., Arts, and Lett. Vol. 23 (1937), pp. 633-643.

THE SMELT, *OSMERUS MORDAX*, IN GREAT BAY, NEW HAMPSHIRE

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ABSTRACT

In the course of a study of the fishery resources of the State of New Hampshire, a spawning run of anadromous smelt, *Osmerus mordax*, was analyzed for age, size, sex ratio, and sexual dimorphism.

Four distinct age groups were present in the run. A 1-year group, while not present in the marketed product, comes into the gear during the spawning season. The predominant age class is 2 years. The next largest age group is the 3-year group and a scattering of 4-year individuals is encountered.

The size of the total population collected during the course of the spawning run was fairly uniform except that a tendency toward smaller size was exhibited near the end.

The sex ratio during the run follows the pattern previously described by investigators of fresh-water smelt. A distinct dimorphism with regard to size differences, coloration, and nuptial tubercle development exists.

A brief description of the gear conditions is included.

The most important fish taken at the present time in the waters of the New Hampshire coast is the common smelt, *Osmerus mordax*. This fish, well known in the inland waters, where it has either become "land-locked" or has been artificially stocked, is an item of considerable importance to a few fishermen who annually invest in the necessary gear for taking it in paying quantities, and to several hundred sports fishermen who fish for it through the ice.

The work of Kendall (1926) is too well-known to warrant repetition here of the general characteristics, habits and distribution of the smelt, and this paper is confined to a study of the composition of the spawning run in the Lamprey River, one of the confluents of Great Bay, and the other streams immediately adjacent to that area.

The types of gear utilized in the fishery are those designed to take advantage of the "schooling" habit. In the commercial fishery two types are encountered. For fishing through the ice, bow-nets are used. These are in effect, large dip nets set through rectangular holes cut in the ice, and are used when the fish are near the mouths of the stream and on the margin of the bay. During the spawning run a larger and more effective type of gear is used, called a weir, in this region. This is a large rectangular trap set permanently in a stream in such a way as to intercept the fish as they move up and down the course. It is a modification of trap nets used in several types of shore fisheries on the North Atlantic and is highly effective. It is a "savings gear," inasmuch as it allows the smaller (one-year) fish to escape.

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[1]Contribution No. 9, Biological Institute of the University of New Hampshire.

The season for taking smelt extends roughly from the first of the calendar year to mid-April. The beginning of the season is largely determined by the formation of ice that is safe enough to travel upon. When the ice is formed the bow-net can be used, and while smelt can be taken by various means as early as September in the lower estuaries the fishermen apparently do not consider it worth while to set the traps since they have to be removed before the freeze. The end of the season occurs about mid-April and is set by New Hampshire law, although some elasticity is allowed and the closing date varies somewhat.

Smelt vary in abundance during a season under the influence of several conditions. A thaw, introducing quantities of fresh water in the estuaries, causes the fish to move from their customary grounds to other parts of the Bay. It is not known if this is a temperature reaction or a response to reduced salinity. The fishermen believe the latter to be the case. The tides, in the narrower channels, govern fishing operations to a degree. As the tide ebbs, the fish have a habit of moving with it in small schools. On the incoming tide, however, the smelt are generally confined to the channel of a stream and large hauls are taken. The appearance of the fish in a definite channel is uncertain during the winter and it is possible to fish over a considerable area without results for several days.

Preliminary studies have been largely concerned with the composition of the catch following the idea that if the nature and composition of the smelt population were known first, explanations of its ecology when studied later would be much more understandable. Therefore, this is but the first of what should be an extensive project that should run over a period of 3 or 4 years. To complete the study one complete generation of smelts should be followed.

Age

A total of 287 individuals were studied to determine their age.[2] Bigelow and Welsh (1924) and others have indicated that the smelt, being school fish, probably associate in age groups; that is, all fish of one age seem to associate and those of another year run together in another school. Several writers comment upon the uniform size of schools observed. Neither of these observations was verified by the present study. The runs contained fish of two predominant age groups

Table 1.—Relative abundance of Great Bay smelt according to age group.

Date collected (1942)	Age group				Total number
	I	II	III	IV	
Jan. 27-29	0	33	27	3	63
April 5	0	51	18	0	69
April 9	10	0	0	0	10
April 19	0	105	40	0	145

and scatterings of two others (Table 1). One-year fish, being smaller than the diameter of the netting used to take them, are never very

[2]By the scale method.

plentiful in the catch, and they are almost always allowed to escape when they are taken. Several hauls observed had only a few or no 1-year fish in them, 10 being the largest number seen at any one time. Two-year fish, on the other hand, are the most abundant fish in the catch, and 3-year fish are next in abundance but quite below the 2-year group in numbers. A few 4-year individuals were found in the winter catch but not enough of them to be an important factor in the fishery. Fishermen say that the 1-year fish remain in schools in the estuaries until fall and that they have often seen what they assumed to be schools of smelt of the year in late summer and early fall. That these fish enter the streams during the spawning run is evidenced by those taken this season. How abundant they are at that time is uncertain.

LENGTH

Two length measurements of fish usually are made by fishery investigators. One, the total length, is from the tip of the snout to the tip of the caudal fin. The other, the standard length, excludes the tail fin. Both of these measurements were made to determine the relationship of one measurement to the other, and to determine if any evidence of sexual dimorphism could be found expressed in this structure. The relationship expressed as a ratio T.L./S.L. varied from 1.12 to 1.17. No significant differences correlated to age or sex in this respect were found.

Henceforth all references will be in terms of the total length.

The length of the age groups is shown in Figure 1. The mean length of 1-year fish is 86.0 millimeters, of 2-year smelt 144.9 millimeters, of 3-year fish 171.0 millimeters, and for the few individuals in the 4-year group 220.0 millimeters. The increment is greatest during the first year. The fish grew 59.0 millimeters in length the second year, 26.0 millimeters the third year, and 49.0 millimeters the fourth. Translated into inches, the 1-year fish are 3.38 inches in length, the 2-year fish average 5.70 inches, the 3-year fish 6.73 inches and the 4-year fish were 8.70 inches. There is a considerable range in size within each of these age groups so that immediate comparison is inadvisable.

The length of the total population ranged from 69.0 to 230.0 millimeters.

WEIGHT

The mean weights of the year classes are shown in Figure 1. One-year fish averaged 2.45 grams, 2-year fish 16.73 grams, 3-year fish 30.62 grams, and the few 4-year fish 55.0 grams. In the avoirdupois scale, the 1-year fish weighed 0.0864 ounces, the 2-year fish 0.59 ounces, 3-year fish 1.07 ounces, and the 4-year fish 1.94 ounces. The trend of Figure 1 denotes a remarkable increase in weight in the 4 years of the smelt's existence. The first increment is 14.28 grams, the second 13.89 grams, the third 24.00 grams. The last value is probably not a true

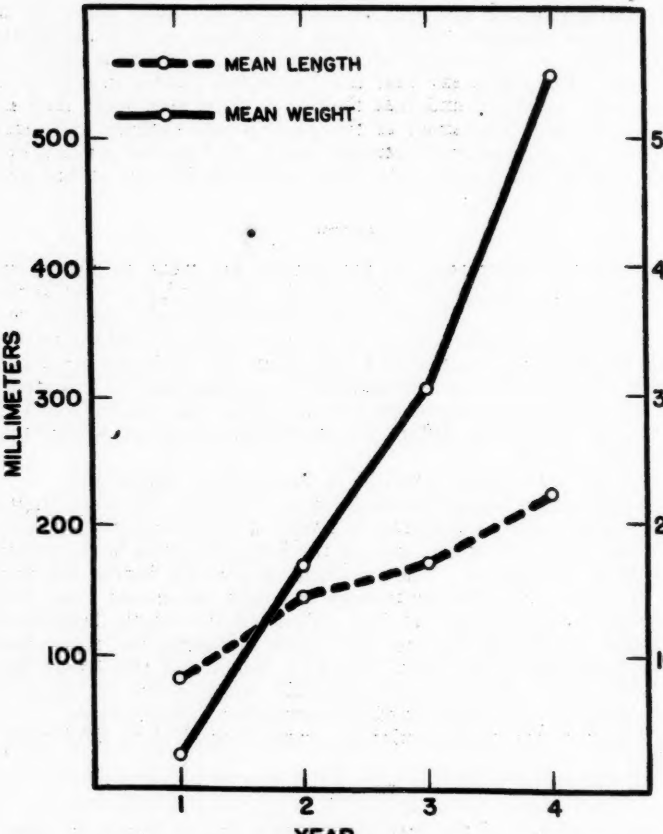

Figure 1.—Comparison of lengths and weights of smelt in Great Bay, New Hampshire, according to age.

one for the entire population of 4-year fish, since there were too few of them in the samples studied to render accurate judgment in this respect.

It has long been thought by fishermen that the smelt taken later in the season were smaller than those taken at the beginning of a run. Studies of the mean weights of the entire populations, as collected, indicate that there is some truth to this assumption. The first collection, made April 5, had a mean weight of 23.50 grams, the next two collections made April 8 and 10 weighed 24.40 and 24.30 grams, respectively, while the last collection taken April 19 averaged 20.25 grams.

Sex

Kendall (1926) has noted the wide disparity in sex among the smelt in single hauls taken from salt water. Hoover (1936) and Green (1930) and others have noted the same occurrence, although less pronounced, in fresh water. The smelt of Great Bay were studied to verify these previous findings and to determine the sex ratio.

The sex ratio of the populations varied considerably when sampled, and a definite trend could be established in this connection. Of 854 smelt taken during the month of April, one-half were males and one-half were females. But in any one sample the ratio of males/females ran as indicated in Table 2.

Table 2.—Sex ratio of Great Bay smelt.

Date of collection (1942)	Number of fish in sample	Number of males	Number of females	Ratio M/F
April 5	69	25	44	0.568
April 8	168	110	58	1.900
April 10	321	166	155	1.070
April 19	296	126	170	0.735
Total	854	427	427	1.000

Considering this small sample in its entirety, the ratio of the sexes is the same, but during the height of the spawning run the males predominate. This has been observed in fresh water by Hoover (1936), Green (1930), and Langlois (1935).

Another aspect of the sex problem in smelt is dimorphism. Langlois (1935) cites three factors that enabled him to distinguish sexes involving (1) color, the same being darker; (2) size, the females being larger; and (3) pronounced nuptial tubercles on the males. Hoover (1936) cited the nuptial tubercles as being useful in differentiating the sexes. Recently Richardson (1942) has described, histologically, the tubercles on the female. The color and the tubercles are apparent during the spawning season of the smelt from Great Bay. Size differences are apparent in measurements. The mean of the total lengths of all the males taken during the spawning run is 150.25 millimeters. The same figure for females is 161.3 millimeters. The females of all age groups are therefore 11.05 millimeters larger on the average than the males.

Sex differences, as expressed by weight, are more pronounced than those expressed by lengths. The mean of the mean weights of the males was 19.00 grams and the mean of the mean weights of the females was 26.64 grams. There was some evidence indicating that this difference becomes more marked as the age of the fish increases.

Table 3.—Sexual dimorphism in dominant age groups of smelt.

Age group	Sex	Mean weight (grams)	Mean length (millimeters)
II	Male	14.04	141.8
II	Female	19.43	148.1
III	Male	24.36	164.2
III	Female	36.89	177.9

SUMMARIZATION:

Difference in length for age-group II = 6.3 millimeters
Difference in weight for age-group II = 5.39 grams
Difference in length for age-group III = 13.7 millimeters
Difference in weight for age-group III = 12.53 grams

The sex of the few 1-year fish collected during the current run could not be determined when the fish were received in the laboratory. Therefore, no data regarding dimorphism for that age and for the 4-year fish are given. The samples were too small in both cases to warrant conclusions.

Literature Cited

BIGELOW, H. B. and W. W. Welsh
1924. The Fishes of the Gulf of Maine. Bull. U. S. Bur. Fish., Vol. 40, pt. 1, pp.

GREENE, C. WILLARD
1930. The Smelts of Lake Champlain. In: A Biological Survey of the Champlain Watershed. Suppl. to 19th Ann. Rep. N. Y. Cons. Dept., 1929, pp.

HOOVER, EARL E.
1936. The Spawning Activities of Fresh Water Smelt, with Special Reference to the Sex Ratio. Copeia, 1936, No. 2, pp. 85-91.

KENDALL, WILLIAM C.
1927. The Smelts. Bull. U. S. Bur. Fish., Vol. 42, pp. 217-375.

LANGLOIS, T. H.
1935. Notes on the Spawning Habits of the Atlantic Smelt. Copeia, 1935, No. 3, pp. 141-142.

RICHARDSON, LAURENCE L.
1942. The Occurrence of Nuptial Tubercles on the Female of *Osmerus mordax* (Mitchill). Copeia, 1942. No. 1, pp. 27-29.

ZYMOGEN GRANULES IN THE FISHES

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Abstract

All of the American Fishes, except the fish-like animals *Amphioxus* and the Cyclostomata (hags and lampreys), have a pancrease in which there is an abundance of zymogen granules. These granules are the precursors of the digestive ferment of the pancreatic juice.

The zymogen granules are very small (less than 3 microns in diameter). They are spherical and situated in the part of the pancreatic cells next to the duct lumen. Their size has no definite relationship to the size of the animal, but in general they are larger in cold-blooded than in warm-blooded animals. They are found in embryos sometime before birth or hatching, showing that the embryos produce their own digestive ferments for digesting the food in the egg, and also in preparation for their independent existence.

There is commingled with the exocrine pancreatic tissue the islet or internal secreting endocrine tissue. This also has minute granules that are especially large in the northern pike (*Esox lucius*).

It is now recognized by physiologists that the pancreas is one of the most, if not the most, important of the digestive organs in the vertegrate series. It is not present in invertebrates and is found unmistakably only in vertebrates in the evolutionary scale above and commencing with the Elasmobranchii (sharks, skates, and rays).

It is true that there are gland-like cells in the intestinal wall near the liver in the Cyclostomata (hags and lampreys), and zymogen granules have been described for these forms in Europe, but in American cyclostomes none could be demonstrated although methods that certainly revealed their presence in sharks and all higher forms were used on abundant materials in all stages of growth and at all seasons of the year.

But commencing with the Elasmobranchii (sharks, skates and rays), all vertebrates have a well defined pancreas, and by proper methods all show the zymogen granules. In some of the bony fishes the pancreas is not easily demonstrated. Some bony fishes were thought to be without a pancreas, but later investigations showed that all possessed pancreatic tissue although it might be in the liver substance or diffused in the abdominal organs. However, in many of the teleosts such as the trouts (Salmonidae) and the northern pike (*Esox lucius*) a pancreas is easily found in the usual place at the beginning half of the duodenum.

The granules of the pancreas were noted by the older histologists Busk and Huxley (1850-54) during the middle of the nineteenth century. Since the granules were highly refractive and stained brown or black with osmic acid and dissolved in caustic potash. many considered

them to be granules of a fatty nature. Even as late as 1876, Krause in his *"Anatomie Generale"* considers them fat particles. However, as early as 1844 the Scotsman, Goodsir, pointed out that all true secretions are present in the cell body in the form of minute particles. Claude Bernard in 1856, and Salter in 1859, interpreted the granules in the pancreatic cells as the precursors of the pancreatic ferment. This supposition was proved correct by all later physiologists, especially by Langley in his classical paper of 1879 on the change in the serous glands during secretion.

In Figure 1 are shown, diagrammatically, and magnified 10,000 diameters, the zymogen granules from the pancreas of a dogfish shark (*Squalus acanthias*) and of a brook trout (*Salvelinus fontinalis*). All sizes of the granules are spherical in form which can be demonstrated by causing them to roll over and over under the microscope. As shown in the diagram, the granules are larger in the brook trout than in the dogfish shark, although the shark is a much larger animal.

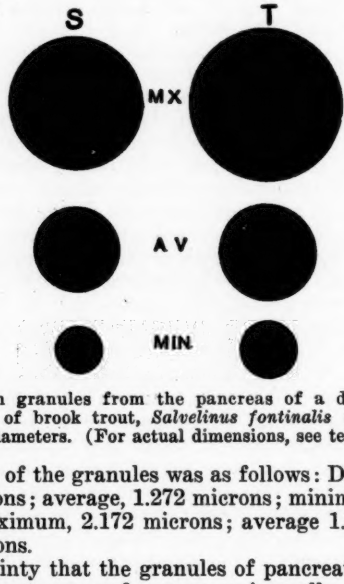

Figure 1.—Zymogen granules from the pancreas of a dogfish shark, *Squalus acanthias* (S), and of brook trout, *Salvelinus fontinalis* (T), magnified 10,000 diameters. (For actual dimensions, see text.)

The actual size of the granules was as follows: Dogfish shark: Maximum, 1.840 microns; average, 1.272 microns; minimum, 0.724 microns. Brook trout: Maximum, 2.172 microns; average 1.367 microns; minimum, 0.778 microns.

With the certainty that the granules of pancreatic cells are of such fundamental importance and are so universally present, it seemed worth while to determine what methods would give the surest proof of their presence and whether they might also help to show the phylogenetic relationship of the different vertebrate groups. This latter hope was not realized, however, for neither the size nor the staining

qualities seemed to have any phylogenetic significance. In general, however, the cold-blooded animals have larger granules than the warm-blooded ones, and of the cold-blooded ones the Amphibia have the largest granules.

While the alcohols preserve many details of structure in tissues, they are not good alone for preserving the zymogen granules of the pancreas. The agent most effective is formalin. So specific is it that the material preserved in it, furnished by the biological supply houses, showed the granules in every specimen. A toad that had been stored in 5-per-cent formalin for 35 years showed the granules to perfection. The persistence of the granules also is demonstrated by the fact that frozen animals give excellent pancreatic zymogen if, after freezing, the tissue is preserved in formalin. Indeed, if 5- to 10-per-cent formalin is added to any of the alcohols or other fixatives used, the granules are well preserved.

As the granules are so small (2 microns and less), it is necessary to use high-power magnification to study them. The microscopic sections should be less than 5 microns thick, or the granules can be isolated by teasing the cells after the tissue has been in 20-per-cent nitric acid for 12 to 24 hours, or in a normal salt solution with 2 cubic centimeters of formalin to the liter (formalin dissociator). In fresh and unstained preparations, the dark-field microscope is invaluable for their study.

It is interesting that with animals having a large amount of food matter in the egg, the growing embryos manufacture their own digestive ferments. For example, in an embryo dogfish shark of 16 centimeters, the pancreas was found to be well-developed and the zymogen granules were of the same size and relative number as in the mother. In birds, the developing chick shows the pancreatic granules in large numbers on the seventeenth day of incubation, illustrating that the embryo itself is producing the enzyme necessary for the digestion of the yolk and albumen of the egg. It also has been found that in mammalian fetuses the pancreas is producing the zymogen granules long before birth. That is, in all vertebrates, preparation for an independent existence is made while the animal is still in the embryonic condition (Needham, 1931).

A word should be added concerning the islet tissue in fishes. There are islet structures in the pancreas of fishes. All sorts of guesses were made as to the significance of this islet tissue. It was called nervous, adenoid, and by other names, but deeper investigation showed conclusively that the islet tissue gave rise to an internal secretion that has a profound effect in carbohydrate metabolism. That is, it is now known that the pancreas is a double organ, so to speak; one part produces the digestice enzymes characteristic of the pancreatic juice (exocrine secretion) and the other or endocrine tissue produces the internal secretion (Warthin, 1922).

In many forms the islet tissue has cells so closely related that the tissue looks like a syncytium (a poly-nucleate structure). In the

northern pike (*Esox lucius*), among the teleosts, the cells of the islets are as distinctly separate as are the exocine cells of the pancreas. The granules of the islet cells, instead of being immeasurably small, are comparatively large, but are much smaller than the zymogen granules of the pancreas.

Literature Cited

Bernard, Claude
1856. Mémoir sur le pancréas. Supplément aux Comptes Rendu des Seances de l'Académie des Sciences, tome premier.

Bensley, R. R.
1911-12. Studies on the pancreas of the guinea pig. American Journal of Anatomy, Vol. 12, pp. 297-388.

Busk, George and Thomas H. Huxley
1850-54. Translation of Kölliker's "Gewebelehre des Menschen," Vol. II, p. 137.

Goodsir, John
1842-44. The ultimate secreting structure. Philos. Trans. R. S. Edinburgh, Vol. 15, pp. 299-304; and "Anatomical Memoirs of John Goodsir," edited by Wm. Turner, Vol. 2, pp. 412-428.

Krause, W.
1876. Allgemeine und microskopische Anatomie, 3d ed; S. 229.

Langley, J. N.
1879-80. On the changes in serous glands during secretion. Jour. of Physiology, Vol. 2, pp. 261-280.

Needham, Joseph
1931. Chemical embryology, Vol. 3, pp. 1310-1318.

Salter, Hyde
1859. Article "Panceras" in Todd's "Cyclopaedia of Anatomy and Physiology," Vol. 5 (Suppl.), pp. 81-114.

Warthin, A. S.
1922. The pancreas as an endocrine gland. Endocrinology and Metabolism (edited by Lewellys F. Barker), Vol. 2, pp. 697-732.

AN EXPERIMENT IN THE USE OF DERRIS ROOT (ROTENONE) ON THE FISH AND FISH-FOOD ORGANISMS OF THIRD SISTER LAKE[1]

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ABSTRACT

Sufficient powdered derris root (guaranteed rotenone content of 5 per cent) to make a concentration of 1:500,000 parts of water was applied to Third Sister Lake on May 6, 1941. Temperatures were unfavorably low and the treatment was not successful in the complete removal of fish. A second application on August 18, 1941 of a slightly greater concentration was sufficient to eradicate the remaining fish. There seemed to be little or no difference in the toleration of the different species of fish, however minnows and the young of game fish were killed in larger numbers at the beginning. It is believed this was the result of their location in shallow water rather than a difference in susceptibility to the poison. Not all fish came to the surface after death.

Live fish taken from the lake before poisoning were placed in traps at different points and at various levels in the lake at the time of each poisoning in order to test vertical and horizontal distribution of the poison. In the first poisoning all fish above the 10-foot level were killed at the end of 30 hours, while those below 10 feet were alive at the end of 5 days when the experiment was terminated. Other fish taken from the river were placed and replaced in the traps until there was no further loss. The surface water remained toxic for about 7 days, while the deep water was never toxic. In the second poisoning the water down to 20 feet in depth contained sufficient rotenone to kill fish. The toxicity of the lake water progressively decreased from the surface down to 20 feet. Water below that depth did not have sufficient oxygen to support fish life.

Laboratory experiments with surface water taken from the lake after poisoning showed that high temperatures increased toxicity. The sequence of death for the four species of fish used was the same in each experiment. Individual fish of the same species showed considerable difference in toleration to rotenone. Fish showing the first signs of distress had their lives prolonged only a short time by removing them to untreated water. They could not be revived completely. Derris powder collected from the surface of the bottom mud the day after poisoning no longer had any observable toxic qualities.

Observations and experiments were made to test the effect of rotenone on lake organisms other than fish. *Corethra, Daphnia, Diaptomus,* and most other zooplankters were very greatly reduced as a result of the treatment. Phytoplankton counts showed no significant reduction in number. Tadpoles were greatly affected during the first poisoning but only slightly so during the second. Leeches and dragonflies of the sub-family Aeshninae were drastically reduced by the first poisoning, while the same species of dragonflies were less effected by the second poisoning.

INTRODUCTION

The present experiment is part of a general investigation being conducted by the Institute for Fisheries Research, Michigan Department

[1]Contribution from the Michigan Institute for Fisheries Research.

of Conservation, and the Zoology Department, University of Michigan, on the relationship between the fish and fish-food organisms of Third Sister Lake. This study is under the general direction of Dr. A. S. Hazzard, Director of the Institute, and Professor Paul S. Welch of the Zoology Department. Permission to use the lake was granted us by the University of Michigan School of Forestry and Conservation which is responsible for the administration of the Saginaw Forest tract upon which the lake is located.

The complete removal of fish from the lake was carried out for the purpose of observing what effect their absence would have upon the various fish-food constituents and to obtain more reliable figures on species and abundance of fish present. It is planned to restore the fish population at the termination of this study.

There is little choice of tools when a complete removal of fish is desired and of those methods tried, poisoning with rotenone is the most practical. The phase of the investigation reported here has only to do with the poisoning procedure and its effect on the fish and fish-food organisms. Other parts of this research will appear as they are completed.

Description of Third Sister Lake.—Third Sister Lake is roughly oval in outline with a surface area of approximately 10 acres and a maximum depth of 55 feet. It lies near the center of Washtenaw County, Michigan, in the Huron River drainage system. This lake has no permanent inlets nor outlets. Its water supply comes mainly from seepage and runoff originating in the surrounding moraines. The outlet which passes through a small marsh is dry most of the year, but may be an avenue of entrance during periods of high water for certain fishes in the Honey Creek and Huron River drainages less than 5 miles below.

About one-fourth of the shore immediately adjacent to the lake is firm and composed of sand and gravel; the remainder is very soft and peaty. The emergent and submerged vegetation zones cover approximately 35 per cent of the lake area and extend from the shore to about the 10-foot contour. The sides of the lake basin are steep, having a sharp "drop-off."

The bottom is composed of soft, finely divided organic material (pulpy peat) between the two and twenty-five foot contours. At depths greater than this the bottom consists of clay overlain by a thin coating of muck.

Third Sister Lake stratifies thermally and chemically during the summer. The average annual bottom temperature is approximately 4°C. and a thermocline develops with subsequent marked depletion of O_2 in the hypolimnion. The water is moderately soft having an average alkalinity of approximately 90 p.p.m. of $CaCO_3$ and a pH range of 6.8-8.4.

General procedure and methods of applying derris.—The first application of derris was made during the forenoon of May 6, 1941. While

the water temperature on this date was far below the optimum desired for the best results, this time was chosen in order to remove the fish before they had spawned and before the aquatic plants were high or dense enough to prevent the recovery of dead fish.

Because of the unfavorable temperature conditions that existed in Third Sister Lake at the time of the first poisoning, there was reason to believe that the treatment had failed to kill all of the fish. Since complete removal was necessary in order to carry out the different phases of this investigation, careful checks were made between May 10 and August 1 by netting and through observations to determine if there were live fish still present in the lake. Gill nets were set on May 14 and during the ensuing 3 days captured 5 large bluegills including 3 females and 2 males, and one male pumpkinseed. On July 16 a large school of small bluegills or sunfish was observed and during the month that followed, these small centrarchids appeared in ever-increasing numbers. It was decided then to make another attempt at poisoning and this was accomplished on August 18 and 19.

The derris powder used had a guaranteed rotenone content of 5 per cent. In the first application, 312 pounds of derris root were used, which amounts to approximately 1 part of powder to 2 million parts of water by weight. Four hundred pounds were used for the second application, making the concentration somewhat greater than the first.

The procedure of mixing and applying the poison was as follows: 10 to 15 pounds of derris powder were placed in a 50-gallon steel drum with one end removed; lake water was then added to fill the drum about three-quarters full. An outboard motor was placed in the barrel and mixing was attained by running the motor. This only takes a minute or so and the resulting mixture is similar in color and consistency to chocolate "malted milk." This suspension was then placed in 10-gallon milk cans and poured from the side of a boat propelled by an outboard motor. In this manner it was well dispersed in the surface water by the churning action of the motor. The courses the boat followed were regular and overlapped until the entire lake was covered. Then the same procedure was followed crossing the first courses at right angles. The entire lake was covered four times in this manner. All of the shallow water near the edges was treated by means of a fire pump or by throwing the solution with a dipper.

In the second application the procedure was the same except that 85 pounds of derris were mixed into a batter and then placed in weighted burlap bags and dragged behind a boat in water at a depth varying between 15 and 25 feet.

Collections.—Samples of the fish, plankton and invertebrate animals were secured before, during and after the poisoning. Fish samples taken before poisoning were secured with gill nets, trap nets and by angling. After poisoning, all of the fish which rose to the surface or which could be reached with dip nets on the lake bottom were recovered for a population study. This procedure is described in another

paper (Brown and Ball, 1943). Plankton samples were obtained by means of a 10-liter plankton trap and bottom samples by the use of Ekman and Peterson dredges.

In addition to observations made on the fish and other organisms as they appeared under natural conditions, certain fish and invertebrate organisms were captured in the lake previous to poisoning and placed in cages at various levels in order to see what effects rotenone might have on them. Laboratory experiments using the treated lake water were also carried out to further test the effect of treated lake water on fish, tadpoles and several of the invertebrates.

The First Poisoning

Conditions in the lake.—Temperature readings were secured and chemical analyses were made of the waters of Third Sister Lake 7 days before and 4 days after poisoning. Temperatures were also recorded on the day before poisoning. These data are summarized in Table 1. The rather favorable conditions during the week previous to the poisoning indicated that temperatures and other factors in general would be favorable for the experiment. However, the weather was cold and rainy for 4 or 5 days preceding the poisoning date and no more favorable on the day of poisoning, causing a drop in the surface temperature of 20°F. The entire surface layer of water down to 15 feet was affected by this change and early in the morning of the poisoning the lake had a maximum temperature of only 48°F. which occurred between the 5- and 10-foot contours. Four days later, after bright, warm weather the water temperatures had returned to levels about equal to those existing the week previous to poisoning. It would seem that the time we chose for our experiment was the most unfavorable from the point of view of temperature that existed during the spring period.

This experience was not without value, however, since it demonstrated that rotenone is not as effective when used in water with low temperatures.

On the poisoning date the aquatic vegetation was still in the very early stages of spring growth. Some of the yellow water lily leaves had reached within a few inches of the surface but the pondweeds in general had not grown more than 4-6 inches above the bottom. The fish population in Third Sister Lake included the following species: Largemouth black bass (*Huro salmoides*), bluegills (*Lepomis macrochirus*), pumpkinseeds (*Lepomis gibbosus*), green sunfish (*Lepomis cyanellus*), mud pickerel (*Esox vermiculatus*), bullheads (*Ameiurus natalis*), chub-sucker (*Erimyzon sucetta*), common suckers (*Catostomus commersonnii*), black-chinned shiner (*Notropis heterodon*), black-nosed shiner (*Notoropis heterolepis*), common shiner (*Notropis cornutus*), golden shiner (*Notemigonus crysoleucas*), Iowa darter (*Poecilichthys exilis*), and mudminnow (*Umbra limi*).

Table 1.—Temperature and chemical conditions in Third Sister Lake before, during and after first poisoning

Depth (feet)	Before April 29, 1941, 2:30 P.M. Air temperature 73° F.					During May 5, 1941, 6 A.M. Air temperature 46° F.	After May 8, 1941, 2:30 P.M. Air temperature 66° F.				
	Temperature, ° F.	O_2, p.p.m.	CO_2, p.p.m.	M.O., p.p.m.	pH	Temperature, ° F.	Temperature, ° F.	O_2, p.p.m.	CO_2, p.p.m.	M.O., p.p.m.	pH
0	65	....	....	....	....	45	64	13.4	0	82	8.0
3	62	....	....	....	....	47	64	....	....	....	....
6	58	....	....	....	....	48	63	....	....	....	....
9	55	13.2	0	82	8.0	48	60	9.8	1	86	8.0
12	53	....	....	....	....	46	53	....	....	....	....
15	47	....	....	....	....	45	49	....	....	....	....
18	44	....	....	....	....	45	45	....	....	....	....
21	....	9.8	0	86	8.0	45	44	5.6	3	88	7.6
24	44	....	....	....	....	....	43	....	....	....	....
27	....	....	....	....	....	....	43	....	....	....	....
30	....	5.6	1	88	7.6	45	42	4.8	5	88	7.5
33	....	....	....	....	....	....	42	....	....	....	....
36	42	....	....	....	....	....	42	....	....	....	....
39	....	3.9	3	88	7.5	44	42	3.8	5	88	7.5
42	....	....	....	....	....	....	42	....	....	....	....
45	....	....	....	....	....	44	42	....	....	....	....
48	....	....	....	....	....	....	42	....	....	....	....
51	....	2.1	5	88	7.2	....	42	2.1	7	88	7.2
54	....	....	....	....	....	....	42	....	....	....	....
57	....	....	....	....	....	43	....	....	....	....	....
60	42	....	....	....	....	....	....	....	....	....	....

Observations on the fish.—The first poison was placed in the lake at about 6:00 A.M. and the first dead and dying fish were observed 20 minutes later. There seemed to be little or no difference in the toleration of the different species of fish to the rotenone poison. However, the minnows and the young of the other fish appeared in larger numbers at the beginning, which may have been due to their greater susceptibility or to their location in the lake. Most of the smaller fish are in shallow water and would naturally come in contact with the poison sooner than those fish found at deeper levels.

Some of the fish floated to the surface immediately upon dying while others sank or remained on the bottom. Both small and large specimens reacted in this manner. The darters, of course, do not float as a rule because of the lack of a swim bladder; however, three darters were found floating the day following the poisoning. A great many of the fish never rose to the surface even after decomposition began to occur. A number of specimens were observed each day for a week and decomposed without leaving their original positions on the bottom. These were mostly small fish; the larger specimens seemed to float more readily and we believe that the fish recovered represent the majority of the larger fish. It is certain, on the other hand, that many small fish remained on the bottom and were never recovered. Thompson and Bennett (1939 a) reported that many of the fish sink after being overcome by rotenone but indicated that such individuals become bloated and rise to the surface a short time after.

Experiments with the fish.—Careful observations were made to determine the length of time the poison was present in quantities sufficient to kill fish at various depths. This was accomplished by placing live fish in minnow buckets or cages of approximately 500 cubic inches in volume and lowering them to different levels in the lake. Eight different locations well-scattered over the lake were chosen in order to test for horizontal as well as vertical distribution of the poison. Cages containing bullheads, largemouth bass and bluegills captured in the lake before poison was administered were placed at the following depths: 4, 6, 7, 9, 11, 16, 35, and 40 feet. The initial check was made approximately 8 hours after the first poison was introduced. All of the cages except the one at 40 feet were examined. This was retained as a control against the others which had to be brought up through the presumably more toxic surface water each time they were examined. It was not certain that fish might be killed by their short exposure to surface water rather than to the poison at the levels which were being tested. It was demonstrated satisfactorily in subsequent experiments that this short exposure had no serious effect on the fish. All of the fish were dead in the cages at 4 and 6 feet. A second examination was made at the end of 12 hours and the fish in the cage at 7 feet were found to be dead. At the end of 24 hours a third examination showed all of the fish suspended at levels between 9 and 40 feet to be alive and in good condition. At the end of 30 hours, how-

ever, the fish at 9 feet were all dead. The last examination was made on the fifth day following the application of derris root and all of the fish in the four deepest cages were still alive and apparently in good health. This would indicate that either the poison did not reach depths beyond 10 feet in concentrations sufficient to kill fish or that these fish were not affected by the poison because of the low temperatures prevailing there.

As a further check on the duration and extent of the poison in the lake, fish (pumpkinseeds, bluegills, largemouth black bass and blunt-nosed minnows) seined from the Huron River were placed in cages and lowered to different levels. The method followed was to place 4-8 fish with representatives of each species in each trap. These traps were lowered quickly to a depth several feet below the desired level before being brought up to the level to be tested. This procedure insured the removal of all surface water which might otherwise have remained in the cages. Tests of this nature were made at regular intervals until all of the fish at all levels remained alive. When fish died, the approximate time before their death was recorded and they were replaced by living specimens. Examinations of the cages were made at either 10- or 24-hour intervals, or both. It did not seem advisable to check the fish oftener than this because it was necessary to haul them to the surface each time in order to see the results. Because of this, we do not have any information on the exact time the fish died but only know that death occurred sometime during the interval between examinations. It is fairly safe to assume, however, that the time required to kill fish used in these experiments was probably less than 5 hours. In other words, if they died at all from the effects of the poison, they did so within this time.

This experiment was begun on May 7, 1941, and cages were placed at the following levels: 0-1, 3, 6, 9, 12, 15, 20, 25 and 30 feet. At the time of the first examination, 12 hours later, all of the fish were dead in waters above the 10-foot level and all were alive below. The fish in the traps below 10 feet were still alive on May 21 when the experiment was terminated 13 days later.

On May 8, live fish were again placed in the four upper cages and were dead when examined 10 hours later. The fish were again replaced the following morning (May 9) and all were dead 24 hours later (May 10). Again they were replaced in the four upper cages and at the end of 10 hours some of the fish were dead in each cage except at the 9-foot level where all of the fish were alive. At the end of 30 hours (May 13) all of the fish in the three upper cages were dead. They were replaced for the final time on that date and all remained alive until the experiment was terminated 8 days later (May 21, 1941).

Additional experiments were carried out to test the dispersal and duration of the rotenone in lake water after removal from the lake. Samples of water were taken between the surface and the 30-foot levels with a Juday bottle and put into half-gallon glass jars. Fish

were then placed in these jars and the time of their survival recorded under different temperature conditions. Four species of fish (large-mouth bass, bluegills, pumpkinseeds and blunt-nosed minnows) averaging about 3 inches in total length were used in these experiments.

The temperature of the water in the jars was controlled within 2 or 3 degrees Fahrenheit except during the first experiment which was conducted at the lake shore.

The first series of water samples was taken 24 hours after the lake had been treated with derris root. One fish of each species was placed in a jar containing lake water soon after the experimental water was removed from the lake. The water was allowed to warm up to the air temperature (61° F.). The temperature and time were recorded at the beginning of the experiment and at the death of each individual. Two identical tests were made on the water from each depth and a similar test was made using surface well water as a control. The results are presented in Table 2.

Table 2.—Time required to kill fish kept in treated lake water from various levels at increased temperatures

Depth of water sample, (feet)	Number of test	Temperature, °F., at beginning	Temperature, °F., at death	Time before death Hours - Minutes
Surface	1	45	61	0 - 46
Surface	2	45	60	0 - 50
6	1	48	58	6 - 15
6	2	48	62	2 - 10
6	3	48	64	1 - 3
10	1	47	61	[1]None killed
10	2	47	61	2 - 15
20	1	45	61	[1]None killed
20	2	45	61	[1]None killed

[1]Fish lived for 3 weeks at which time the experiment was terminated. Water temperatures ranged between 58° and 64° F. during this time.

Water from the 20-foot level did not contain sufficient poison to kill fish even when the temperature was raised to 61°F. In one test on water from the 10-foot level, fish were killed in 2¼ hours and in another similar test none of the fish died even though they were held for 3 weeks. None of the water samples appeared to be toxic to fish until the water temperature had been raised at least to 57° F.

In these experiments, the fish died in the following order: Large-mouth black bass, bluegill, pumpkinseed, blunt-nosed minnow. Detailed records were not made of the actual difference in time required to kill fish of each species but the differences were known to be small in most instances and not altogether significant.

In a second experiment, samples of lake water were taken at intervals of 3 feet from the surface to 30 feet, 48 hours after poisoning. These were then transported to the laboratory for the purpose of testing the vertical distribution of poison in the lake.

All water samples were raised to a temperature of 69°-70°F. before fish were introduced, and kept at this temperature for the duration of the experiment. The elapsed time before death was recorded. Controls

Table 3.—Time required to kill fish in treated lake water from various levels in Third Sister Lake

Depth, (feet)	Temperature, °F.	O_2, p.p.m. at time of death (average)	Time before death, minutes (average)
Surface	69	5.7	38
3	69	6.6	37
6	69	6.2	40
9	69	6.1	44
12	70	4.7	[1]....
15	70	6.6	[1]....
20	70	7.2	[1]....
30	70	6.1	[1]....
Control	70	5.5	[1]....

[1]Where no time is stated, fish were alive at end of experiment.

using tap water were set up in a similar manner. The size and species of fish used were the same as those described for the above experiment.

Three samples from each depth were tested simultaneously and an average of the data from each series is recorded in Table 3.

The species of fish used in this experiment showed the same sequence of death as in the first experiment. None of the fish died in water samples taken below 9 feet. This is in agreement with observations made in the lake. As is shown in Table 3 the oxygen in all of these experiments remained well above the critical point. The average time between the beginning of the experiment and the first symptoms of distress was 10 minutes, and the average time between distress and death was 30 minutes.

In order to test what effect aeration would have on the toxicity of lake water, the same samples used in the above experiment from the surface and at 9 feet were aerated vigorously for 30 minutes after the dead fish from the above experiment had been removed. Fish of the same species introduced into this aerated water died in 42 minutes. The water temperature was 70°F. and the oxygen 6.4 p.p.m. at the time of death.

An attempt was made to revive fish which had shown the first signs of distress in surface lake water. These fish were removed to tap water which was aerated throughout the experiment. None of the fish recovered although the period before death was 10 minutes longer than for those fish left in the surface lake water. Smith (1940) reported that he revived trout which had lost their equilibrium due to rotenone poison. Most observers, however, have found that fish showing distress from poison will not revive on being transferred to untreated water.

Lake water samples were taken at intervals following the poisoning and experiments were conducted to test their toxicity to fish. On the sixth day following the poisoning, fish died in water from the 6-foot level which had been raised to 78°F. but were not affected in this same water kept at 65°F. On the tenth day none of the water samples used showed any toxicity even when raised to 80°F. There is considerable variation in the time required for different waters treated

with rotenone (derris root) to lose their toxicity. Leonard (1939) reported that with a concentration of 1 p.p.m., the water in his experimental aquaria was no longer toxic to bluegills and sunfish after 20-41 hours. Hamilton (1942) also reported the quick disintegration of the poison, and shows that with concentrations even as high as 10 p.p.m. his test solutions were no longer toxic to fish after 24 hours. Thompson and Bennett (1939) stocked Fork Lake in Illinois without loss of fish four days after poisoning. Vestal (1942) stated that Gull Lake in California remained toxic for 12-26 days, and Smith (1940, 1941) reported that in Potter's Lake, New Brunswick, the water was still toxic 18 days after treatment and in the Nova Scotian Lakes it remained toxic for 30 days.

A brownish substance was found in plankton and bottom samples from the deep area of the lake soon after poisoning. A microscopical examination of this material left little doubt but that it was powdered derris. Some of this material was placed in a jar of lake water and this mixture was then warmed to 75°F. Fish were placed in this jar and suffered no ill effects.

Observations on fish-food organisms.—Regular, bimonthly collections of plankton were taken from top to bottom in Third Sister Lake at 10-foot intervals during the entire period of this investigation. Partial counts have been made on these collections and the number of organisms per liter estimated in accordance with the usual methods. Identification of organisms was carried only to the larger groups except for about 10 predominant forms which were identified to genus.

Comparisons have been made between collections taken immediately before and after poisoning and, as well, between similar periods of the prevoius year. Only large and important changes in the plankton population would be recognizable by our methods but small differences would not have significance anyway because of the irregular, almost sudden, natural changes so characteristic of plankton populations.

Most of the phytoplankton groups showed little or no change following the introduction of rotenone, which could be attributed to the poison. A gradual decrease throughout the summer was noticeable for the Chroococcales with an accompanying increase in the diatoms (Bacillarieae) and *Dinobryon*. The dinoflagellate *Peridinum* completely disappeared 3 weeks after the first poison and did not reappear in collections until almost a year later.

In the zooplankton, noticeable reductions did occur, some of which we believe have significance. This was most obvious in the entromostracan genera of *Daphnia* and *Diaptomous*. *Daphnia* completely disappeared 2 days after poisoning and did not reappear in collections until 5 weeks after the second poisoning (Figure 1). *Diaptomous* disappeared along with *Daphnia* but reappeared a little sooner, i. e., 1 month after the second poisoning. Both of these organisms maintained more or less stable populations throughout this same period during the previous year. *Cyclops* showed a sharp decline immediately fol-

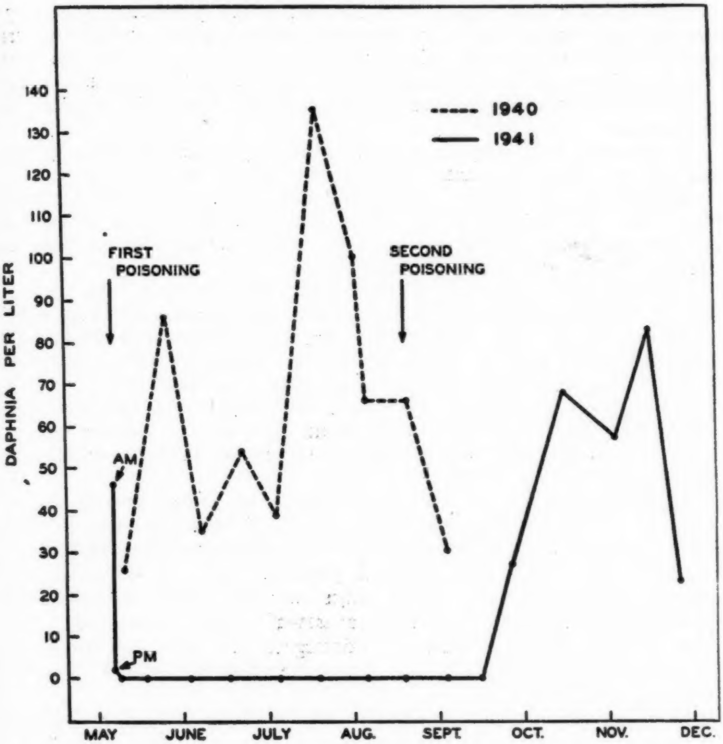

Figure 1.—Estimated number of *Daphnia* per liter before (1940) and after (1941) poisoning

lowing each poisoning date but partially recovered in the interim. Collections made 6 weeks after the first poisoning and 4 weeks after the second showed about the same number of *Cyclops* recorded for the similar period of the preceding year. *Epichura,* which ordinarily appears very sporadically in this lake, did not show in any collections for the entire year after the first poisoning date. This may or may not be significant.

While rotifers were present in all collections following the poisoning the group as a whole appeared to be considerably reduced as compared with the same period of the previous year.

Observations were made on the aquatic invertebrate population before, during and after poisoning the lake. Regular sampling of an in-

tensive nature was carried out for two years preceding poisoning, throughout the summer when the two treatments with rotenone were made, and for 6 months following the last poisoning. Samples were not numerous enough to detect small differences in populations but we believe they were adequate to show gross changes of aquatic invertebrates.

In general, the samples show no very significant changes before, during and after poisoning which could not be explained by the inadequacy of our method, emergence, migration or general seasonal variation. On the other hand, we do know that certain organisms were at least partially affected as shown by experiments and field observations at the time of each poisoning period.

Corethra were observed to be dying and coming to the surface within a short time after the first poison was introduced. The windward vegetation area of the lake was literally covered with dead *Corethra* larvae the day following the first poisoning. Field observations substantiated the experimental work described below in that large numbers of leeches, aeschnine dragonflies and tadpoles succumbed to the poison and were found dead in the shallow waters near shore. Meehan (1942) likewise observed that *Corethra* and leeches were readily killed by rotenone.

Experiments with fish food organisms.—An experiment to ascertain the effect of the poison on the fish food organisms was carried out at the lake during the poisoning. The organisms used in this experiment were collected in the lake prior to poisoning and placed in special screen wire cages. These cages were then distributed between the surface and the 6-foot level at several points on the lake. All cages were examined at intervals during the five days subsequent to poisoning. On the fifth day the experiment was terminated. The results appear in Table 4.

Practically all of the organisms that died did so within the first 24 hours after Derris Root was introduced into the water. The only organisms which were seriously affected included the aeschnine dragon-

Table 4.—The mortality of certain invertebrate organisms and tadpoles confined for 5 days to cages kept at various places in Third Sister Lake following the treatment of the lake waters with derris root

Organism	Depth of trap		
	Surface	3 feet	6 feet
Leeches	Dead	Dead	Dead
Snails (*Planorbis, Gyraulus, Physa, Amnicola*)	Alive	Alive	Alive
Amphipods (*Gammarus, Hyalella*)	Alive	Alive	Alive
Anisoptera nymphs:			
Libelluline nymphs	Alive	Alive	Alive
Aeschnine nymphs	Dead	Dead	Dead
Gomphine nymphs	Alive	Alive	Alive
Zygoptera nymphs	Alive	Alive	Alive
Trichoptera larvae	Alive	Alive	Alive
Diptera larvae:			
Chironomus	Dead	Dead	Dead
Corethra	Dead	Dead	Dead
Tadpoles	Dead	Dead	Dead

flies, leeches, *Corethra* and tadpoles. The Chironomidae which lived about 48 hours probably died from unfavorable conditions resulting from the change of habitat rather than from the poison. The leeches and dragonflies were killed within 12 hours. Tadpoles (*Rana catesbeiana*) were also killed, although the time required was greater.

The Second Poisoning

Temperature and chemical analyses were made six days before, during, and 22 days after the second poisoning. These data are summarized in Table 5.

Surface water temperatures on August 18 and 19 were near the maximum for the summer and therefore were very favorable to poisoning. There was a zone of water, however, between 18 and 25 feet which still retained sufficient oxygen to support fish and which was rather cold (45°-53°F.) for the best effects of the poison. An attempt to increase the concentration of rotenone in this zone was made by dragging burlap bags containing derris through it.

The aquatic vegetation on this date was near its peak of abundance. This was particularly true for the pondweeds (*Potamogeton natans, P. amplifolius*) and the yellow water lilies (*Nuphar advena*).

Some observations of the invertebrate organisms indicated that, with the exception of leeches, the general abundance of the various groups in the lake was about the same as in other summers. The leeches were undoubtedly drastically reduced by the first poison. The absence of *Gammarus* at this time of year in Third Sister Lake is not at all unusual. We do not know the reason. Aeschnine dragonflies were very abundant in spite of the apparent high mortality at the time of the first poisoning.

Tadpoles were extremely numerous—no doubt the results of spawning after the first poisoning and also because of the removal of the predatory fish.

The only fish observed to be present were bluegills and pumpkinseeds.

As a result of this poisoning, many thousand young bluegills and sunfish were killed. Part of these floated to the surface and part remained on the bottom, there to decompose and become engulfed by filamentous algae. The adult fish which were recovered included two largemouth bass, 12 large bluegills, 1 common shiner and 1 mudminnow.

Gill-net sets and observations between the date of this poisoning and June 1942, failed to reveal that any fish were left in the lake. However, in June 1942 long-eared sunfish appeared. Since this species was not present at the time of the first poisoning, it may be assumed that they entered through the outlet of the lake during the extremely high water stages in June.

Experiments with fish.—The same methods employed in the first

Table 5.—Temperature and chemical conditions in Third Sister Lake before, during and after the second poisoning

Depth (feet)	Before August 12, 1941					During August 18, 1941					After September 10, 1941				
	Temperature (°F.)	O_2 (p.p.m.)	CO_2 (p.p.m.)	M.O. (p.p.m.)	pH	Temperature (°F.)	O_2 (p.p.m.)	CO_2 (p.p.m.)	M.O. (p.p.m.)	pH	Temperature (°F.)	O_2 (p.p.m.)	CO_2 (p.p.m.)	M.O. (p.p.m.)	pH
0	82	9.0	0.0	93	8.4	84	9.2	0.0	88	8.5	74	8.0	0.0	88	8.4
3	80	....	....	....	....	80	....	....	....	....	71	....	....	....	....
6	....	8.1	0.0	94	8.4	80	....	....	....	....	68	....	....	....	....
9	....	8.4	0.0	94	8.5	77	11.1	0.0	88	8.4	67	9.0	0.0	88	8.4
12	75	....	....	....	....	75	....	....	....	....	63	....	....	....	....
15	65	19.8	0.0	84	9.1	65	16.9	0.0	88	8.0	60	....	....	....	....
18	53	....	....	....	....	53	....	....	....	....	52	....	....	....	....
21	47	9.5	8.0	84	7.4	47	6.4	10.0	89	7.4	49	6.3	5.0	88	8.0
24	45	3.7	18.0	84	7.0	45	2.0	15.0	90	7.0	47	....	....	....	....
27	44	....	....	....	....	....	....	....	....	....	45	....	....	....	....
30	43	0.0	21.0	84	6.9	43	0.0	20.0	90	6.8	43	0.0	10.0	84	7.0
33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
39	....	....	....	....	....	....	....	....	....	....	....	0.0	15.0	88	6.8
42	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
48	....	....	....	....	....	42	....	....	....	....	....	....	....	....	....
51	42	....	....	....	....	....	....	....	....	....	....	0.0	20.0	88	6.7
54	....	....	....	....	....	....	....	....	....	....	42	....	....	....	....

poisoning to determine the dispersal and effectiveness of the poison in the lake were used at the time of the second poisoning. The fish used in the experiments were collected in Huron River and included 3 to 4 inch bluegills, pumpkinseeds and largemouth bass. Cages containing representatives of each of these species were placed at the surface, 3, 6, 10, 15, 20, and 22 feet before the lake was poisoned. The cages were examined 24 hours after the poisoning. At this time the fish in the traps at and above the 15-foot level were all dead and those below the 15-foot level were all alive.

As previously described, powdered derris was distributed at depths between 18 and 25 feet. The cages were lifted again in 24 hours and all fish were dead in those below 15 feet.

A second series of experiments was conducted to determine the relationship between temperature and the toxicity of the water at various depths in the lake. Samples of water were collected from the lake surface and at depth intervals of five feet down to and including 30 feet 48 hours after poison was introduced. These were taken to the laboratory and used in the experiments. Fish were introduced into several jars filled with water from the same sample. These jars were then maintained at different temperatures and records were kept of the length of time before the first signs of distress and at the death of the fish. The results of these experiments are presented in Table 6.

None of the experimental fish placed in water from the 25- or 30-foot levels died even at higher temperatures and none of the tadpoles died in any of the experiments. At any given temperature the elapsed time before the death of the fish progressively increased from the surface to 25 feet. This quite definitely shows that the surface water contains a higher concentration of the poison. At a temperature of 45°F., fish were not affected even when placed in surface water. In general, down to the 25-foot level, where fish died they did so more quickly at higher temperatures regardless of the depth of the sample. There was a marked difference between the time required to kill largemouth black bass and pumpkinseeds under the same condition. At 50°F. pumpkinseeds survived 2½ hours longer than largemouth black bass.

Water samples collected from the surface, 5, 10, 15 and 20 feet, 72 hours after poisoning, were used for laboratory experiments. Both largemouth black bass and pumpkinseeds died in the water from the surface, 5- and 10-foot levels within 90 minutes (temperature 72°F.). Fish placed in water from the 15- and 20-foot levels were still alive at the termination of this experiment 2 days later (temperature 72°F.).

Experiments with fish-food organisms.—A number of experiments conducted during the first poisoning to test the effect of rotenone on some of the invertebrates were repeated during the second poisoning. Several species of invertebrates collected in the lake were confined to

Table 6.—The relationship between temperature and toxicity of treated lake water
[LMB = largemouth bass; PS = pumpkinseed]

Sample (depth)	Sample	Species	Temperature, °F.	Elapsed time to distress of first fish, (minutes)	Elapsed time to death of last fish, (minutes)	Alive at termination of experiment
Surface	A	2-LMB	45	....	....	5 hours
	A	1-PS				
	B	2-LMB	50	40	70	....
	B	1-PS				
	C	2-LMB	50	50	90	....
	C	1-PS				
	D	1-LMB	50	60	125	....
	D	1-PS				
	E	3-LMB	50	40	60	....
	F	2-PS	50	120	210	....
	G	2-LMB	74	10	15	....
	H	2-PS	74	10	20	....
	I	2-Tadpoles	74	....	....	2 days
5 feet	A	1-PS	50	95	140	....
	A	1-LMB				
	B	2-PS	57	125	180	....
	C	2-LMB	57	20	35	....
	D	2-LMB	74	15	20	....
	E	2-LMB	74	15	25	....
	F	2-Tadpoles	74	....	....	2 days
	G	2-LMB	45	....	....	5 hours
	G	1-PS				
10 feet	A	2-PS	56	....	....	6 hours
	B	2-LMB	56	....	185	....
	C	1-PS	74	10	25	....
	D	2-PS	74	30	70	....
	E	1-PS	74	15	25	....
	F	2-LMB	47	....	....	5 hours
	F	1-PS				
	G	2-Tadpoles	68-72	....	....	2 days
15 feet	A	2-PS	50	....	240	....
	B	2-LMB	50	....	125	....
	C	2-LMB	74	10	24	....
20 feet	A	2-LMB	74	....	198	....
	B	1-PS	74	....	....	2 days
	C	1-PS	70	....	....	2 days
	D	1-PS	70	....	300	....
25 feet	A	1-PS	68-74	....	....	2 days
	A	1-LMB				
	B	1-PS	70-74	....	....	2 days
	B	1-LMB				
	C	2-LMB	75	....	....	2 days
30 feet	A	2-LMB	70-74	....	....	2 days
	B	2-PS	70-74	....	....	2 days

cages and placed just below the surface and at the 2- and 4-foot depths prior to poisoning. No *Chironomus* or *Corethra* larvae from the deep water were used in these experiments because it was known that these forms would not live for any length of time in the warmer surface water even before poisoning. No *Gammarus* was available in the lake at the time of the second poisoning and so was omitted from the experiments.

Cages were examined each day and the dead organisms were counted and removed. Table 7 contains the summarized results of these experiments.

The results of the second series of experiments are similar in most respects to those secured during the first poisoning except for the

Table 7.—Mortality of fish-food organisms when retained in treated lake water from the surface, 2-foot and 4-foot depths

Organism	Surface		2 feet		4 feet	
	Number of organisms	Hours to death	Number of organisms	Hours to death	Number of organisms	Hours to death
Leeches	....	12	....	....	....	....
Snails:						
Planorbis	....	[1]....	....	[1]....	2	72
					4	[1]....
Physa	....	[1]....	....	[1]....	....	[1]....
Amnicola	....	[1]....	....	[1]....	....	[1]....
Amphipods:						
Hyalella	....	[1]....	....	[1]....	....	[1]....
Anisoptera nymphs:						
Libelluline	....	[1]....	....	[1]....	....	[1]....
Gomphine	....	[1]....	....	[1]....	....	[1]....
Aeschnine	4	[1]....	....	3	48	[1]....
	3	48	....	1	24	[1]....
Zygoptera nymphs	....	[1]....	....	[1]....	....	[1]....
Trichoptera larvae	....	[1]....	....	[1]....	....	[1]....
Midges	....	[1]....	....	[1]....	....	[1]....
Tadpoles	1	24	2	48	5	24
	3	72	2	[1]....	1	[1]....
	1	96	....	....	....	....
	1	[1]....	....	....	....	....
Duration of experiment	8 days		3 days		4 days	

[1]All lived for duration of experiment.

aeschnine dragonflies. As has been described, all of the aeschnine dragonflies died very soon in the cages in the first poisoning experiments but not in the experiments of the second poisoning. A few died at the end of 24 hours but most of them lived 48 hours or longer and several were still alive when the water was no longer toxic to fish. A few individuals were observed to survive high concentrations of derris near the dock where the powder and water were mixed.

From these experiments and observations on the invertebrates in the lake it is evident that certain organisms such as leeches, *Corethra* and aeschnine dragonflies may be seriously reduced by the treatment of the lake with derris powder. On the other hand, it is evident that most of the invertebrate organisms are not seriously affected by treatments of this kind.

Literature Cited

Brown, C. J. D., and R. C. Ball
1943. A fish population study of Third Sister Lake. Trans. Am. Fish. Soc., 1942, Vol. 73, pp. 000-000.

Hamilton, Howard Laverne
1941. The biological action of rotenone on fresh-water animals. Iowa Acad. Sci. Vol. 48, pp. 467-469.

Leonard, J. W.
1939. Notes on the use of derris as a fish poison. Trans. Am. Fish. Soc., 1938, Vol. 68, pp. 269-279.

MEEHEAN, O. LLOYD
1942. Fish populations of five Florida lakes. Trans. Am. Fish. Soc., 1941, Vol. 71, pp. 184-194.

SMITH, M. W.
1940. Copper sulphate and rotenone as fish poisons. Trans. Am. Fish. Soc., 1939, Vol. 69, pp. 141-157.
1941. Treatment of Potter's Lake, New Brunswick, with rotenone. Trans. Am. Fish. Soc., 1940, Vol. 70, pp. 347-355.

THOMPSON, DAVID H., and GEO. W. BENNETT.
1939. Lake management reports. 2. Fork Lake near Mount Zion, Illinois. Ill. Nat. Hist. Surv., Biol. Notes, No. 9.

VESTAL, ELDEN H.
1942. Rough fish control in Gull Lake, Mono County, California. Calif. Fish and Game, Vol. 28, No. 1.

APPENDICES

AMERICAN FISHERIES SOCIETY
Organized 1870

Certification of Incorporation

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certifying in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interest of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

Seymour Bower	(Seal)
Theodore Gill	(Seal)
William E. Meehan	(Seal)
Theodore S. Palmer	(Seal)
Bertrand H. Roberts	(Seal)
Hugh M. Smith	(Seal)
Richard Sylvester	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS

OF THE

AMERICAN FISHERIES SOCIETY

(As Amended August 26, 1942)

ARTICLE I

Name and Object

The name of the Society shall be the American Fisheries Society.

The objects of the Society shall be to promote the cause of fish culture and its allied interests; to gather and diffuse information on all questions pertaining to fish culture, fish, and fisheries; and to unite and encourage those interested in fish culture, and fisheries problems.

ARTICLE II

Membership

The membership of this Society shall be classified as follows: Active, Club, Libraries, State, Patron, Honorary, and Corresponding.

Active Members.—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society. The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. Any active member may upon payment of fifty ($50.00) dollars become exempt from the payment of annual dues though retaining the privilege of active membership for the duration of his life.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

Libraries.—Libraries may be admitted to membership upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for libraries shall be two ($2 00) dollars per year.

State Memberships.—Any state, provincial or federal department of the United States, Canada or Mexico may become a state member of this Society upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for State membership shall be twenty ($20.00) dollars per year.

Patrons.—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member of this Society upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President of the United States, the President of Mexico, the Governors of the several states, and the Secretary of the Interior of the United States, the Governor-General of Canada, the Lieutenant-Governors of the several Canadian provinces, and the Dominion

Minister in Charge of Game and Fisheries shall be honorary members of this Society while occupying their respective official positions.

Election of Members between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized to act upon all applications for memberships received while the Society is not in session.

Rights and Duties of Members.—Active members in good standing only shall have the right to vote at regular or special meetings of the Society. Any member is held to be in good standing whose dues are not more than one year past due. In case of non-payment of dues for one year, proper notice shall be given the member by the Treasurer in writing, and if such member remains delinquent one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of one year, except upon payment of arrears and current dues.

Transactions.—Each member of the Society in good standing, except honorary members, shall receive one copy of the annual volume of *Transactions.* Only members in good standing may present papers either by reading or by title at the annual meetings and publish them in the *Transactions;* except that outstanding non-members invited by the President of the Society to participate in the program shall be exempted from this requirement. No member may have listed on the program of an annual meeting, or present, or have published in any one volume of the *Transactions* more than two papers; and for purposes of this rule joint authorships shall compare equally with sole authorships.

Quorum.—Twenty voting members shall constitute a quorum for the transaction of business at annual or other meetings of the Society.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund.—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests, and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a president, a first vice-president, and a second vice-president, all of whom shall be elected for the term of one year and shall be ineligible for reelection to the same office until a year after the expiration of their terms; a secretary, a treasurer, a librarian, and five vice-presidents, one to be in charge of each of the following divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

The officers specified above, and the president of the previous year, shall form an Executive Committee* with authority to decide the policies of the Society and to transact such business of the Society as may be found necessary. The Executive Committee is authorized to fill from the membership any vacancies that may occur in any offices between meetings. A majority of the Executive Committee shall constitute a quorum.

Only members in good standing who are in attendance or have been in attendance at one of the two immediately preceding meetings shall be eligible for election to the offices listed above and for appointment to any committee, except the members of the Committee on Common and Scientific Names of Fishes.

The officers shall be elected by a majority vote at a regular meeting, a quorum being present.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the regular and all special meetings of the Society and shall be ex-officio chairman of the Executive Committee.

The first Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, conduct its correspondence, promote its membership, and arrange for regular and special meetings. The Secretary shall also attend to the publication and distribution of the annual issuance of Transactions.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of seven thousand, five hundred ($7,500) dollars to be approved by the Executive Committee and to be paid for by the Society. The offices of Secretary and Treasurer may be occupied by the same person.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed *Transactions*, and shall have charge of the sale of surplus copies of such *Transactions*.

The Vice-President of each division shall become conversant with the subject of his division and present a report on it at the regular meeting, placing emphasis upon developments during the past year.

Committee members shall cooperate in performing the functions of their appointments and render reports as directed by the President.

ARTICLE V

Standing Committees

The standing committees shall be Executive; International Relations; State and National Relations; Common and Scientific Names of Fishes; and Publications. The Committee on Publications shall be appointed by the President. The Executive Committee shall be selected as provided for by Article IV.

The Committee on International Relations shall be composed of seven members selected by the nominating committee for election, and its duties shall be to exchange ideas pertaining to the various phases of fisheries administration, biology, including fish culture, with foreign fishery biologists, conservation and fishery administration officials, fish-culturists or aquicultural societies. A report based on such exchange should be presented at each regular meeting.

The Committee on State and National Relations shall be composed of five members selected by the nominating committee for election, and its duties shall be to act in behalf of the Society as a coordinating and advisory board for the

*The Council was discontinued and the Executive Committee enlarged by Amendment to By-Laws, September 11, 1935.

consideration of interstate and National-State fishery problems. A report shall be presented at each annual meeting.

The Committee on Common and Scientific Names of Fishes shall be composed of seven members selected by the nominating committee for election. Its duties shall be to establish and maintain in the files of the Librarian of this Society a correct check list of the species of fishes occurring in the waters of the United States and Canada. This list should contain both scientific and common names.

The Committee on Publications shall be composed of five members, and its duties shall be to select and edit manuscripts submitted for publication. Papers shall be submitted ready for publication within thirty days after the close of the regular meeting. Such papers, together with the minutes of the regular and special meetings and the reports of the various divisions and committees, shall be published in an annual volume which shall be numbered in series with previous volumes and entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY.

ARTICLE VI

Meetings

The regular meeting of the Society shall be held once a year, the time and place to be decided upon at the preceding meeting, or, in default of such action, by the Executive Committee. Special meetings shall be called by the President upon approval of a majority of the Executive Committee.

ARTICLE VII

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Application for memberships.
4. Reports of officers:
    a. President
    b. Secretary
    c. Treasurer
    d. Vice-Presidents of Divisions
    e. Standing Committees
    f. Special Committees
5. Committees appointed by the President:
    a. Committee of five on nomination of officers and standing committees for the ensuing year.
    b. Committee of five on time and place of next meeting.
    c. Committee of five on resolutions.
    d. Auditing committee of three.
    e. Committee of three on program.
    f. Committee of three on publicity.
    g. Committee of five on publications.*
6. Reading of papers and discussions of same. In the reading of papers preference shall be given to the members present.
7. Miscellaneous business.
8. Adjournment.

ARTICLE VIII

Changing By-Laws

The By-Laws of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least twenty-five members are present at said regular meeting.

*A resolution adopted August 24, 1937 established a staggered committee of five and provided that each incoming President shall appoint one new member for a term of five years and designate the Chairman of the Committee.

AMERICAN FISHERIES SOCIETY

LIST OF MEMBERS

(Showing year of election to membership)

HONORARY MEMBERS

The President of the United States.
The President of Mexico.
The Secretary of the Interior of the United States.
The Governors of the several States.
The Governor-General of Canada.
The Lieutenant-Governors of the several Canadian Provinces.
The Dominion Minister in Charge of Game and Fisheries.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harpers Ferry, W. Va.
'04 Denbigh, Lord, London, England.
'40 Gordon, Seth, % Game Commission, Harrisburg, Pa.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15 Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 California Barrel Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore & Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co., C. W. Weld, Mgr., 301 Brannon St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3d St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The, W. A. Barbour, Mgr., 443 Mission St., San Francisco, Calif.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware & Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Pope and Talbot, Foot of 3d St., San Francisco, Calif.

'15 Puget Sound Navigation Co., Seattle, Wash.
15 Ray, W. S. Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California, James B. Brady, Gen. Mgr., 2nd and Folsom Sts., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

LIFE MEMBERS

'00 Beeman, Henry W., New Preston, Conn.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wis.
'42 Brown, Louis P., Insurance Bldg., Glens Falls, N. Y.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
'26 Cary, Guy, 55 Wall St., New York, N. Y.
'04 Coker, Dr. Robert E., University of North Carolina, Chapel Hill, N. C.
'01 Dean, Herbert D., Northville, Mich.
'15 Folger, J. A., Howard and Spencer Sts., San Francisco, Calif.
'12 Fortmann, Henry F., 1007 Gough St., San Francisco, Calif.
'22 Grammes, Charles W., Hamilton Park, Allentown, Pa.
'03 Gray, George W., Marine Biological Laboratory, Woods Hole, Mass.
'28 Hall, W. A., Co., Gardiner, Mont.
'10 Hopper, George L., Havre De Grace, Md.
'23 Kienbusch, C. O., 12 E. 74th St., New York, N. Y.
'22 Kulle, Karl C., Suffield, Conn.
'26 Lackland, Sam H., 69 So. Ann St., Mobile, Ala.
'26 Low, Ethelbert I., 256 Broadway, New York, N. Y.
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'16 Nelson, Charles A. A., Lutsen, Minn.
'07 Newman, Edwin A., 4205 8th St., N. W., Washington, D. C.
'31 Nicholas, E. Mithoff, 20 S. 3d St., Columbus, Ohio.
'10 Osburn, Prof. Raymond C., Ohio State University, Columbus, Ohio.
'04 Palmer, Dr. Theodore S., 1939 Biltmore St., N. W., Washington, D. C.
'10 Radcliffe, Dr. Lewis, 5600 32nd St., N. W., Washington, D. C.
'00 Thompson, W. T., 121 N. Willson, Bozeman, Mont.
'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'12 Townsend, Dr. Charles H., 1033 Astoria St., Coral Gables, Fla.
'11 Valette, Luciano H., Echevarria F. C. S., Buenos Aires, Argentina, S. A.
'22 Walcott, Frederic C., Norfolk, Conn.
'98 Ward, Dr. Henry B., 1201 Nevada St., Urbana, Ill.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.

ACTIVE MEMBERS

'13 Adams, William C., Dept of Conservation, Albany, N. Y.
'29 Ainsworth, A. L., Tuxedo Fisheries, Tuxedo Park, N. Y.
'33 Albert, W. E., Jr., Lansing, Iowa.
'38 Alderson, I. T., Von Hoffman Press, 101 S. 9th St., St. Louis, Mo.
'31 Aldrich, A. D., P. O. Box 1365, Tulsa, Okla.
'34 Alexander, George J., Parliament Bldgs., Victoria, B. C., Canada.
'36 Allen, Edward W., Northern Life Tower, Seattle, Wash.
'29 Allen, William Ray, Dept. of Zoology, University of Kentucky, Lexington, Ky.
'32 Allen, Dr. William S., P. O. Box 7, Sherbrooke, P. Q., Canada.
'42 Allison, Leonard N., Grayling, Mich.
'40 Anderson, Bertil G., Dept. of Botany and Zoology, West Virginia University, Morgantown, W. Va.
'42 Anderson, William W., 1609 Masonic Temple Bldg., New Orleans, La.
'24 Annin, Harry K., Spring Street, Caledonia, N. Y.
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'36 Bailey, Dr. Reeve M., Dept. of Zoology and Entomology, Iowa State College, Ames, Iowa.
'32 Bailliere, Lawrence, Stoutland, Mo.
'27 Baker, Clarence M., 2 South Carroll St., Madison, Wis.
'36 Baker, Dr. Clinton L., Southwestern, Memphis, Tenn.
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'23 Bangham, Dr. Ralph V., Wooster College, Wooster, Ohio.
'05 Barbour, Prof. Thomas, Museum of Comparative Zoology, Cambridge, Mass.
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'38 Barram, John, R. R. 5, Picton, P. O., Canada.
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'42 Carlander, Kenneth D., Bureau of Fisheries Research, Dept. of Conservation, St. Paul, Minn.
'40 Carpenter, Ralph G., 2nd, Wolfeboro, N. H.
'41 Carr, Harold B., U. S. Civil Aeronautics Authority, Earle Bldg., Washington, D. C.
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'40 Cooper, Edwin L., Hunt Creek Experiment Station, Lewiston, Mich.
'33 Cooper, Dr. Gerald P., Univ. of Maine, Orono, Me.
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'42 Doan, Kenneth H., Franz Stone Laboratory, Put-in-Bay, Ohio.
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'32 Eschmeyer, Dr. R. William, T.V.A., Norris, Tenn.
'04 Everman, J. W., Supervisor of Public Utilities, Dallas, Tex.
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'35 Ewers, Dr. Lela A., Cottey College, Nevada, Mo.
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'28 Fearnow, Theodore C., Berkeley Springs, W. Va.
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'27 Gordon, Seth, Game Commission, Harrisburg, Pa.
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'28 Grammes, J. Frank, Grammes Brook Trout Hatchery, 1119 Linden St., Allentown, Pa.
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'34 Griffiths, Francis P., Dept. of Hort. Man., Massachusetts State College, Amherst, Mass.
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'42 Grossman, Harold, Fawn River State Fish Hatchery, Orland, Ind.
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'38 Hall, Cornet, Redbridge, Ont., Canada.
'41 Hammer, Ralph C., Chesapeake Biological Laboratory, Solomons Island, Md.
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'40 Hart, J. S., University of Toronto, Toronto, P. O., Canada.
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'41 Hasler, Dr. Arthur D., Dept. of Zoology, University of Wisconsin, Madison, Wis.
'33 Hawes, Harry B., Transportation Bldg., Washington, D. C.
'38 Hayes, Elgin W., Hornings Mills, Ont., Canada.
'04 Hayford, Charles O., State Fish Hatchery, Hackettstown, N. J.
'35 Hazard, T. P., Peace Dale, R. I.
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'15 Hildbrand, Dr. Samuel F., Div. of Fishes, National Museum, Washington 25, D. C.
'32 Hile, Dr. Ralph, U. S. Fish and Wildlife Service, University Museums, Ann Arbor, Mich.
'38 Hills, A. P., Custom House, St. John, N. B., Canada.
'23 Hogan, Joseph R., State Fisheries, Lonoke, Ark.
'39 Hoglund, Melvin L., U. S. Fish and Wildlife Service, Estacada, Ore.

'37 Holland, R. P., 80 Gaylor Rd., Scarsdale, N. Y.

'36 Holloway, Ancil D., U. S. Forest Service, Glen Bldg., Atlanta, Ga.

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'33 Hosley, N. W., Connecticut State College, Storrs, Conn.

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'13 Huntsman, Dr. A. G., University of Toronto, Toronto, Canada.

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'32 Jackson, Charles E., Asst. Director, U. S. Fish and Wildlife Service, Washington 25, D. C.

'38 Jacocks, West, Chamber of Commerce, Columbia, S. C.

'28 James, Milton C., U. S. Fish and Wildlife Service, Washington 25, D. C.

'39 Jarvis, J. Willard, State Game Commission, Portland, Ore.

'32 Jobes, Dr. Frank W., U. S. Fish and Wildlife Service, University Museums, Ann Arbor, Mich.

'40 Johnson, Bernard W., Como Bluff Hatchery, Rock River, Wyo.

'36 Johnson, Fred F., 5521 Colorado Ave., N. W., Washington, D. C.

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'26 Kaul, William, Saint Marys, Pa.

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'18 New York Public Library, 476 Fifth Ave., New York, N. Y.
'22 New York State College of Agriculture Library, Ithaca, N. Y.
'18 New York State Library, Albany, N. Y.
'22 Ohio State University Library, Columbus, Ohio.
'36 Oklahoma A & M College, Stillwater, Okla.
'27 Library, Oregon State Agricultural College, Corvallis, Ore.
'38 Pacific Biological Station, Nanaimo, B. C., Canada.
'22 Library Association of Portland, 10th and Yamhill Sts., Portland, Ore.
'37 Library of the Legislature, Quebec, P. Q., Canada.
'36 Queen's University Library, Kingston, Ont., Canada.
'22 Scientific Library Division, P. O. Box 774, Manila, P. I.
'21 Scripps Institution of Oceanography, La Jolla, Calif.
'41 State College of Washington, College Station, Pullman, Wash.
'38 U. S. Fish and Wildlife Service, 2725 Montlake Blvd., Seattle, Wash.
'37 University of California, Berkeley, Calif.
'22 University of Illinois, Urbana, Ill.
'20 University of Indiana Library, Bloomington, Ind.
'36 University of Maine, Orono, Me.
'20 University of Michigan Library, Ann Arbor, Mich.
'21 University of Nebraska Library, Lincoln, Neb.
'38 University of Saskatchewan, Saskatoon, Sask., Canada.
'21 University of Toronto Library, Toronto, Canada.
'19 University of Washington Library, Seattle, Wash.
'39 W. K. Kellogg Bird Sanctuary, Augusta, Mich.
'20 Yale University Library, New Haven, Conn.

CORRESPONDING MEMBERS

'22 Director, All-Russian Agricultural Museum, Fontanka 10, Leningrad, U.S.S.R.
'22 Director of Fisheries (British Malay), Singapore, Straits Settlements.
'22 Library, National Museum of Natural History, Paris, France.
'10 Stead, David G., Watson Bay, New South Wales, Australia.

INSTRUCTIONS FOR PREPARING AND EDITING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1941)

Please check each item below before the final typing of your manuscript and help your Society reduce the costs of publication, save your editorial committee (which works gratis) much needless work, time, and expense, and avoid delay in the publication of the *Transactions.*

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals (Government Printing Office Style Manual; University of Chicago Style Manual). Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. **Manuscript must be typewritten double-spaced.** Use one side only of sheet. Do not fold manuscript. Write manuscript only in simple upper and lower case, do not use all capital letters for any purpose and underscore only when italics are intended.

2. **Carbon copies will not be accepted.** Do not use thin, transparent paper. Heavy bond paper is preferred.

3. **Margins** at top, bottom, and both sides should be about 1½ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. **Pages** must be numbered in consecutive order, including the bibliography, tables, charts, and photographs. Tables, charts, and all illustrations must be inserted near their place of reference in the text.

5. **Illustrations.** Make separate pages of tables with headings (not of leader work), of diagrams, charts, and illustrations, and limit the number to those absolutely necessary to clarify or supplement text. *Tables and cuts cost money!* Only sharp, glossy photos can be used. All drawings, charts, and diagrams should be prepared in waterproof India ink on Bristol Board, other perfectly smooth white paper or cardboard, or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the shading lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed 4¼ by 6½ inches (inclusive of legends) when reduced. All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend. The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, figures, maps, charts, and tables, and designate all of these, except tables, as figures, numbering them in consecutive order with Arabic, not Roman, numerals.

6. **Footnotes** in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the

text by two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1.

7. **The title** of the manuscript, together with the author's name (write out in full either one or both of the Christian names and do not use the word "by"), position or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer:

REPORT ON THE DISEASES OF BROOK TROUT

JOHN EDWARD DOE

Department of Conservation, Lansing, Michigan

8. **Underscore** (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius*. *Do not underscore any words unless italics are intended.*

9. Inspect papers in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in parentheses, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any references not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below to be placed at end of paper:

LITERATURE CITED

DOE, JOHN C., J. W. BROWN, and H. W. GREEN.
1939. Report on the diseases of brook trout. Trans. Am. Fish. Soc., 1938, Vol. 68, pp. 450-461.

Note that the year of publication precedes the title and the year of the meeting is stated in the reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and very inaccurate. Help us correct this situation.

11. **Tables.** Every table should have a heading and must be typewritten on a separate page. Insert tables among the text pages near the points where they are discussed. In preparing tables please be certain that they are not too large to appear on a single printed page. Number tables consecutively with Arabic, not Roman, numerals (1, 2, 3, etc.). Abbreviate the word "number" (No.) when referring to a special number—not when referring to quantity or things. Spell all other words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date*, in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

Item	Number of fish	Percentage of total	Average length in millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.25

12. **Capitals.** Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to a particular State, Government, and to organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Boulder Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but lower-case a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher orders.

13. **Abbreviations.**

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures—F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

"*Number*," when preceding figures—No. 125; otherwise spell out.

"*United States*," if preceding name of a department or a bureau or a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana*.

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5-September 2.

Measures and weight, except p.p.m.—6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage—12 per cent, a percentage of 25.5.

14. **Numerals.** Spell out all *isolated* numbers less than 10, but use figures in a grounp of enumerations when any one number of that group is 10 or greater. Do not spell out numbers of two or more digits (except round numbers of approximations: estimated at five hundred; a thousand fish), and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were nine trout. There were 9 trout, 120 bass, and 50 pike.

Use figures for all enumerations of quantities and measurements, such as dimension, weight, area, volume, distance (if fraction spell out, as one-half mile), clock time, time, money, percentage, degrees, proportion or ratios, age, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth inch). For example: $3.00 per 20 pounds; 5 feet 6 inches; about 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes at 30

minutes past 4 o'clock; 25.5 per cent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; the 1st of January, 1938, the 20th day of March; 1937-38; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch trout; 120 6-inch trout.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

Spell out such indefinite expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout.

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. **Use of hyphen.** Many compound words when used as nouns are not hyphenated but require use of the hyphen when used as adjectives. For example note the following sentences: "This was *cold water.*" "Trout are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

Write "largemouth" and "smallmouth" as one word when referring to black bass.

III. SUBJECT MATTER

16. **Condense your paper** to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, direct, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. **Papers which are too poorly written will be rejected.** Do not expect your Editorial Committee to rewrite your manuscript.

17. **Be definite in references to species.** The scientific name, and wherever needed the *complete* common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "bass," "trout," "pike," and "pickerel" apply to any one of several species. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth black bass," "brook trout," "rainbow trout," etc.

18. **Things to avoid.** Words that do not appear in the dictionary in the sense employed should be avoided. The *words* "case," "instance," "show," "found," "gave," and "present" are overworked in manuscripts, the same word sometimes appearing several times in one paragraph.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives.* Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: "*This* was true in every *case.*" "*The mortality was high* in every *pond.*"

19. **Abstract of paper.** Give a condensed summary or brief abstract at the beginning of your paper.

Prepared by the Committee on Publications.
February, 1937 (revised 1941).

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